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SOME FACTORS INVOLVED IN THE COLORIMETRIC DETERMINATION OF THE pH OF SOILS[1]

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When practical application is to be made of the laboratory determinations of soil pH, it is necessary not only that the procedure used be standardized, but also that the results obtained approximate very closely to field conditions. This was found to hold true in the case of certain soils in the Okanagan Valley. Standardized methods of pH determination did not always give results which appeared reliable for practical application in the field. An investigation has accordingly been conducted into certain of the steps involved in the laboratory procedure. The results reported herein deal with the effects of diluting the soil solution and with the effects of filtering through a porous clay pot.

REVIEW OF LITERATURE

Effects of Dilution.—In 1916, Sharp and Hoagland (*16*) obtained only slight changes in the hydrogen ion concentration with widely varying ratios of soil to water. In 1917, Gillespie and Hurst (*6*) found that the pH of the 1 : 2 ratios of soil to water averaged 0.14 higher (with nine soils) than that of the 1 : 1 ratios. In 1918, Plummer (*11*) compared the soil solution at the optimum moisture content with the same upon dilution, and found the former more alkaline with alkaline soils and more acid with acid soils. Fisher (*5*) reported in 1921 that diluting the soil solution five or ten times in order to decrease the turbidity made no measurable difference in the pH. Salter and Morgan (*14*), using nine acid soils, found in 1923 that dilution decreased the acidity in every case. Soil-water ratios were tested of 1 : 1 to 0.32 : 1000, and the pH rise with successive dilutions was found to be remarkably steady. The differences between the pH at a calculated moisture content of 20% and that of a 1 : 5 ratio mixture ranged to as high as 0.85 pH. Joseph and Martin (*7*) found considerable variation upon diluting the soil solutions of heavy clays. Atkins (*1*) reported in 1924 that when soils were re-extracted several times, the successive portions tended to become less alkaline with alkaline soils, and less acid

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with acid soils. Barnette, Hissink and van der Spek (*2*) varied the amount of soil used from 5 grams to 80 grams with 200 cubic centimeters of water, and found little effect on the pH of acid soil suspensions. Pierre (*10*) in 1925 compared the pH of displaced solutions with that of 1 : 5 extracts, and found the latter either slightly higher or slightly lower, with no great differences. After the more soluble acids and salts had been washed out of the soil, dilution up to 1 : 50 made practically no difference in pH. In 1931, Perkins (*9*) found that greater dilution tended to give a more alkaline reaction, while Best (*3*) reported a higher pH at the 1 : 5 ratio than at the 1 : 1 ratio. In 1932, Puri (*12*) obtained little difference between the 1 : 1 and the 1 : 5 ratios. The latter were higher in pH more often than the former, with the greatest difference reported being 0.63 pH.

The above references indicate that there has been considerable variation in the resulting pH when different investigators have diluted the soil solution with successive portions of water; some workers have obtained no differences in pH that are of any practical significance, some have obtained less acidity with acid soils, and some have obtained less alkalinity with alkaline soils.

Effects of Filtering Through Porous Clay Filters.—In 1921, Fisher (*5*) filtered soil-water suspensions through Pasteur-Chamberland filters, and obtained a progressive increase in acidity with successive aliquots of the filtrate. Barnette, Hissink and van der Spek (*2*) reported in 1924 a decrease in acidity on passing the suspensions of four acid soils through porous clay "bougies." There was considerable discrepancy between duplicates. Parker (*8*) in 1925 sucked solutions of known phosphate content through both new and previously used Pasteur-Chamberland filters. He found that if the solution was high in phosphate and the walls of the filter contained little that was readily soluble, the latter was enriched at the expense of the former; while if the filter contained much soluble phosphate the reverse process took place. Snyder (*17*) reported an increase in acidity when alkaline soil suspensions were clarified with a Pasteur-Chamberland filter. Thus filtering through porous clay filters has been found by various investigators to produce changes in the pH, though the direction and amount of these changes have apparently shown no uniformity. It might be noted too that filtering through filter paper has also been shown by a number of investigators (*1, 2, 10, 17*) to have variable effects upon the pH.

EFFECTS OF DILUTION

Procedure.—Samples of representative soil types were collected from a number of points in the Okanagan valley, and were air dried. Solutions were obtained from fifteen of these samples at the moisture holding capacity, by displacement. As it was desired to avoid filtration as much as possible, a modification was adopted of the sprinkling method of Schloesing (*15*) as quoted by Russell (*13*). From 400 to 500 grams of soil were wetted to the moisture holding capacity and allowed to stand the same length of time as the corresponding extracts (as noted below). The soil was then packed into a glass tube two inches in diameter, with a coarse cotton cloth tied over the bottom. Water containing a dye (carmine) was poured on top of the soil to a depth of one or more inches, more being added as re-

quired. The drippings from below were collected in small lots and tested for pH without further treatment. It was found that the first few cubic centimeters usually showed a little different pH to that of the second lot, but in succeeding samples very little if any change occurred until the dye appeared in the solution. After the first lot, also, the turbidity was seldom great enough to lessen the accuracy of the pH readings. Accordingly, all the drippings were lumped together except for the first and last lots, which were discarded.

Extracts were made of some fifty of the samples (including the fifteen soils noted above) in soil water ratios of 1 : 1, 1 : 2, 1 : 4, 1 : 8 and 1 : 64. In a number of cases the 1 : 16 and 1 : 32 ratio extractions were also obtained. No correction was made for the moisture content in the air dry condition. In each case, the mixture of soil and distilled water was stirred for about one minute in a glass jar, and was then allowed to stand covered for 20 to 24 hours. A few soils were allowed to stand for 48 hours, on account of high turbidity at the shorter period. Samples of the supernatant liquid were then obtained with a pipette, and used without further treatment for pH determinations.

Preliminary experiments showed that on many of the soils tested the quinhydrone electrode method of pH determination was not satisfactory. The drift was often excessive, both on clear and on turbid solutions. Colorimetric methods were accordingly used throughout these tests, the results being recorded to the nearest 0.05 pH. Many of the solutions were somewhat turbid; but correction was readily made for this factor by the use of the box comparator. Allowing the suspensions to remain standing for a longer time in order to give quite clear solutions made little if any difference in the recorded pH.

Results.—Dilution of the soil solution was found to affect the pH in an entirely different manner with different soils. The majority of the soils tested showed a very high buffer capacity. Some changed no more than 0.05 pH when diluted from the moisture holding capacity to a ratio of 1 : 64. The majority changed in pH not more than 0.30. There were quite a few however which changed more than this, as great a difference as pH 0.80 being recorded. The greatest change noted between the moisture holding capacity and the 1 : 1 ratio was 0.35 pH. On the whole the most acid soils of those tested tended to rise a little in pH with increasing dilution, while the most alkaline tended to fall somewhat. Those between were quite variable. All the samples were found to be within a pH range of 5.8 to 8.7 at a 1 : 1 ratio.

Some of the soils were quite consistent in their pH change, being the same, progressively higher, or progressively lower with increasing dilution. Others, however, were quite variable, showing most unexpected drops or rises between the two extremes of soil-water ratios tested. The variability was indeed great enough to demonstrate that calculations of the average changes from point to point with dilution would be practically valueless.

In order to illustrate some of the types of variation obtained, the results from six soils are tabulated in Table 1, and illustrated graphically in Figure 1.

TABLE 1.—EFFECT OF DILUTION ON pH OF SOIL SOLUTION

Dilution	Soil 1*	Soil 2*	Soil 3*	Soil 4*	Soil 5*	Soil 6*
	pH	pH	pH	pH	pH	pH
Moisture holding capacity	8.20	7.60	7.25	7.20	6.40	6.30
1 : 1 ratio	7.85	7.60	7.30	6.90	6.35	6.10
1 : 2 ratio	7.70	7.65	7.30	6.85	6.40	6.40
1 : 4 ratio	7.60	7.70	7.30	6.85	6.55	6.50
1 : 8 ratio	8.00	7.55	7.35	6.90	6.60	6.45
1 : 16 ratio	8.00	7.40	7.35	6.80	6.70	6.50
1 : 32 ratio	8.00	7.35	7.35	6.70	6.80	6.50
1 : 64 ratio	7.95	7.25	7.35	6.65	6.85	6.50

*Soil 1—A heavy alkali soil, A_1 horizon.
*Soil 2—A subsoil sand, C horizon.
*Soil 3—An orchard sandy loam, A_2 horizon.
*Soil 4—An orchard silt loam, A_2 horizon.
*Soil 5—An orchard sandy loam, A_2 horizon.
*Soil 6—An orchard loamy sand, A_2 horizon.

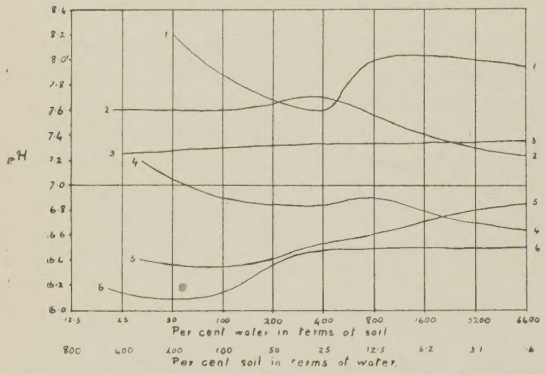

FIGURE 1. Effects of dilution on pH of soil extraits.

Each curve in the figure starts at the moisture holding capacity of the soil, and finishes at the 1 : 64 ratio. Owing to the fact that readings were taken only to the nearest 0.05 pH, some smoothing has been done to the curves. It will be noted that the soil-water ratios are measured along the horizontal axis in geometrical progression. The purpose of this is to give greater emphasis to the lower moisture contents.

EFFECTS OF FILTERING THROUGH A POROUS POT

Since water extracts at even the lower moisture percentages showed some digression in pH from the displaced solutions, it was felt that it would be safer to obtain the solution from soil at or near the moisture holding capacity. The displacement method is however somewhat tedious, especially with heavy soils. It was thought that a more rapid method would be to suck the solution through a porous porcelain filter, as was done by Briggs and McCall (*4*) in 1904; and that by discarding the first portion of the filtrate, the error produced by filtering might be rendered negligible.

Procedure and Results.—The procedure employed was quite a simple one. The soil to be tested was wetted to a "puddly" condition—*i.e.*, just above the moisture holding capacity—and was allowed to stand covered for 24 hours. It was then packed tightly around a Livingston atmometer (Type 3C), which was connected to a suction pump giving a pull of 50 to 60 cm. of mercury. In a few minutes, a clear sample of the solution appeared inside the atmometer.

Preliminary tests were made by this procedure on a number of soils. It was found that in some cases the successive portions of the filtrate either rose or fell rapidly in pH; further that duplicates of the same soil seldom gave exactly the same result. Although with some soils the results appeared to be fairly satisfactory, in other cases they were questionable. It was decided accordingly to test the nature of the pH changes by the use of solutions of known pH.

Distilled water was sucked through atmometers which had been in previous use in obtaining soil filtrates. The procedure produced a marked change in the pH of the water, which rose from pH 6.1 to as high as pH 7.4. Solutions of known pH, including clarified soil solutions, were then sucked through. In some cases, the pH was the same after suction as before, in some cases it was higher, and in some cases lower. By way of illustration, the results obtained on three previously clarified 1 : 5 soil extracts are given in Table 2.

TABLE 2.—EFFECTS OF FILTERING ON pH OF SOIL EXTRACTS

—	Solution A	Solution B	Solution C
	pH	pH	pH
Unfiltered solution	7.30	7.70	6.40
Filtrate:—First 100 cc.	7.35	7.20	6.75
Second 100 cc.	7.30	7.35	6.60
Third 100 cc.	7.30	7.50	6.50
Fourth 100 cc.	7.35	7.55	6.40
Fifth 100 cc.	—	7.60	6.40

The direction and amount of the change on filtering appeared to depend largely on the pH of the previous solution drawn through the same atmometer. The previous soil tested influenced also the amount of solution which it was necessary to suck through and discard before the correct pH was reached. In some cases as much as 500 cc. of solution was filtered and tested without the filtrate having yet reached the same pH as the original solution.

It was found that by soaking the atmometers well in dilute HCl, sucking distilled water through them and then baking them to get rid of the HCl, distilled water could then be drawn through without any change in pH. When this had been accomplished, however, the next solution filtered was changed considerably toward the acid side.

Owing to the difficulty of interpreting the results obtained, it was finally decided to abandon this approach.

DISCUSSION

Soil acidity is quite commonly determined by the use of soil extracts, at soil-water ratios of 1 : 1, 1 : 2, 1 : 2.5 and 1 : 5. The extract method has the advantage that it is quite simple and requires little actual working time. The displacement method is somewhat more tedious, though it gives results which can be accepted as approximating more closely to actual field conditions.

The results noted above would indicate that some caution needs to be exercised in using the extract method. The pH at the 1 : 5 ratio for example was found to show marked discrepancies from that at the moisture holding capacity, with sufficient frequency to make the use of this ratio of questionable value in making practical application to the treatment of alkali soils. The 1 : 1 ratio also showed some discrepancy, but of less degree and with less frequency. This ratio is to be recommended in preference to the wider ratios.

Some variation from the 1 : 1 ratio may be used to advantage on certain types of soil. With sandy soils, extracts can be obtained at ratios closer than the 1 : 1. With soils high in organic matter, on the other hand, it is necessary to use a wider ratio than the 1 : 1, as this proportion provides no supernatant liquid. In any case, it would appear that if the extract method is to be used, the lowest dilution possible can be considered the most reliable.

It was claimed by Salter and Morgan (*14*) that if the pH is determined on extracts of 1 : 5, 1 : 25, and 1 : 125 ratios, the results can be plotted and the pH at the moisture holding capacity determined by extrapolation. In the work reported herein, however, it was found that the pH curve sometimes changed markedly in direction in passing from the higher soil-water ratios to the lower ratios; so that extrapolation gave a pH at the moisture holding capacity which was in some cases even less accurate than that at the 1 : 1 ratio.

It was claimed by Pierre (*10*) that if the most soluble acids and salts are first washed out of the soil, the pH will then change very little if any upon dilution, and will accordingly represent more nearly the true, stable hydrogen ion concentration of the soil. The process of acid and salt removal, however, must obviously change the soil solution such that the results obtained are not applicable to field conditions.

The use of atmometers for the purpose of obtaining a clear soil solution shows little or no promise, in so far as pH determination is concerned. There are too many possible sources of error. It might be noted that the effects of filtering on the individual ions were not determined; but in this respect the work of Parker (*8*) is significant, in showing the effects on at least one ion (phosphate) which is known to affect in turn the pH of the solution. It is possible that the changes in pH brought about by filtering are associated with the retention or release by the porous pot of several ions.

SUMMARY

1. The soil solution was obtained from soils at the moisture holding capacity by displacement, without filtering. Extracts were also made, in ratios varying from 1 : 1 to 1 : 64. It was found that as the soil solution was diluted from the moisture holding capacity to a ratio of 1 : 64, the pH was changed in different manner in different soils. The change was quite small with most soils, but was over pH 0.5 with some. Dilution tended to reduce the pH of the most alkaline soils, and to increase that of the most acid soils. The changes with successive dilutions were not always consistent.

2. The soil solution was obtained from soils at the moisture holding capacity by suction through a porous porcelain pot. It was found that in the passage of the solution through the walls of the pot, its pH was frequently changed. Tests with solutions of known pH showed that in some cases more than 500 cc. needed to be sucked through before the correct pH was obtained.

3. It is suggested that in the use of extractions for pH determination, the lowest ratio of water to soil that can be used is the most reliable.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation of the helpful criticism given by Dr. H. R. McLarty, Officer-in-charge of the Laboratory of Plant Pathology at Summerland, and by Mr. R. C. Palmer, Superintendent of the Experimental Station at Summerland, in the preparation of this paper.

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Résumé

Quelque facteurs qui aident à la détermination du pH des sols colorimétriquement. Par J. C. Wilcox. Station expérimentale fédérale, Summerland, C.-B.

La solution de terre a été tirée de sols à la capacité d'absorption d'eau, par déplacement, sans filtration. Il a été également préparé des extraits, dont les relations variaient de 1:1 à 1:64. On a constaté qu'à mesure que la solution de terre était diluée à partir de la capacité d'absorption d'eau jusqu'à une relation de 1:64, le pH subissait différents changements dans différents sols. Ce changement était très peu marqué dans la plupart des sols, mais il dépassait le pH de 0.5 dans d'autres. La dilution tendait à réduire le pH des sols les plus alkalins, et à augmenter celui des plus acides. Les changements obtenus avec les dilutions successives n'étaient pas toujours réguliers. La solution de terre a été tirée des sols au point de capacité d'absorption d'eau par succion à travers un pot en porcelaine poreuse. On a constaté qu'au cours du passage de la solution à travers les parois du pot, le pH était souvent changé. Les essais faits sur des solutions d'un pH connu ont démontré que dans certains cas il fallait aspirer plus de 500 cc. avant d'obtenir le pH exact. L'auteur est d'avis que dans l'utilisation des extractions pour déterminer le pH, la relation la plus faible d'eau au sol qui peut être employée est aussi la plus sûre.

A CHEMICAL EXAMINATION OF A DEGRADED GLENMORE CLAY[1]

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INTRODUCTION

Agriculture in the southern portion of the Interior of British Columbia is largely limited to areas under irrigation. Since irrigation systems are costly, it is natural that the type of agriculture should be intensive, and that available land should be utilized to the fullest extent possible. Due to favourable climatic conditions, tree fruit growing has developed as the major industry of the region.

The average size of an orchard is from 10 to 15 acres, and as it takes about 12 years for a tree to come into commercial bearing, it follows that any catastrophe that results in even partial crop failure, is of extreme importance. This means that every square foot of soil must be productive if production is to be maintained at its maximum, and that the difference between profit or loss may depend in many instances on the health of a very few trees. Consequently soil problems on small areas, which might be neglected under extensive farming, are of considerable importance under intensive tree fruit growing.

In the Glenmore valley, a part of the irrigated Okanagan and close to the city of Kelowna, a soil condition has been developing that threatens the future of the valley as a fruit growing area. The history of the area goes back about 25 years, when the irrigation system was first installed. At that time practically the whole valley was planted out to tree fruits. For the first few years the trees grew vigorously, but as the root systems spread out, blocks of trees in different parts failed to maintain their previous growth. Later many trees died out entirely, or showed such poor growth as to become unproductive, and the land was allowed to revert to pasture. There are other cases where the trees have a starved appearance, and even difficulty is experienced in maintaining cover crops. This condition is extremely serious for each year the area of affected trees increases.

Growers in this area are now wondering what the future of the valley will be. "Will the remaining orchards," they ask, "be eventually killed out? Is reclamation possible, or must the district adjust itself to a new, less intensive type of agriculture?" These questions are of great importance, for if a less intensive type of farming is to be adopted, then changes will have to be made in the irrigation system, and costs will have to be proportioned according to the different productive values of the land.

This paper presents an investigation as to the essential chemical differences or changes that have been brought about through the degradation of the once fertile soil. It is hoped that the results may aid in determining the future utilization of the area.

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[1] Paper read by title at the meeting of the Soils Group of the C.S.T.A. at the University of Alberta, Edmonton, June 25, 1935.

[2] Assistant Soil Surveyor, Soil Survey Branch.

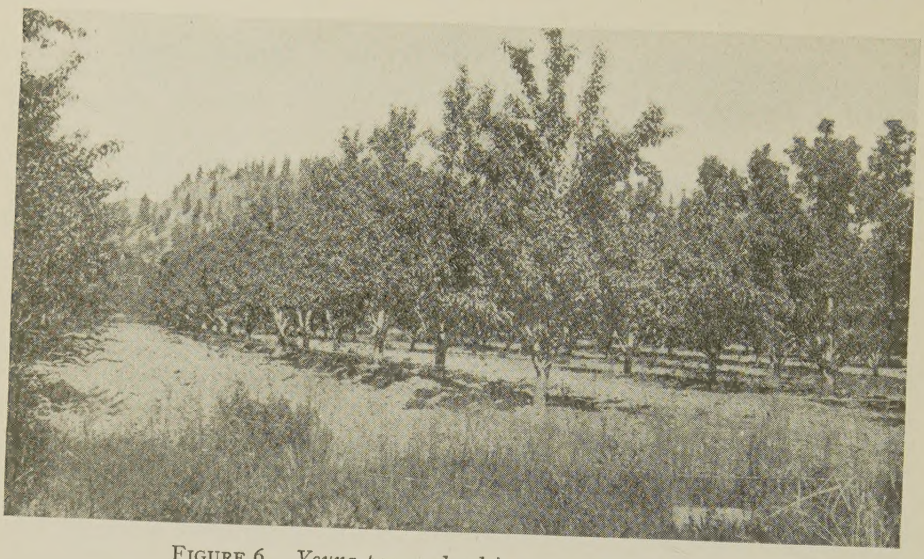

FIGURE 6. *Young pear orchard in a well drained phase.*

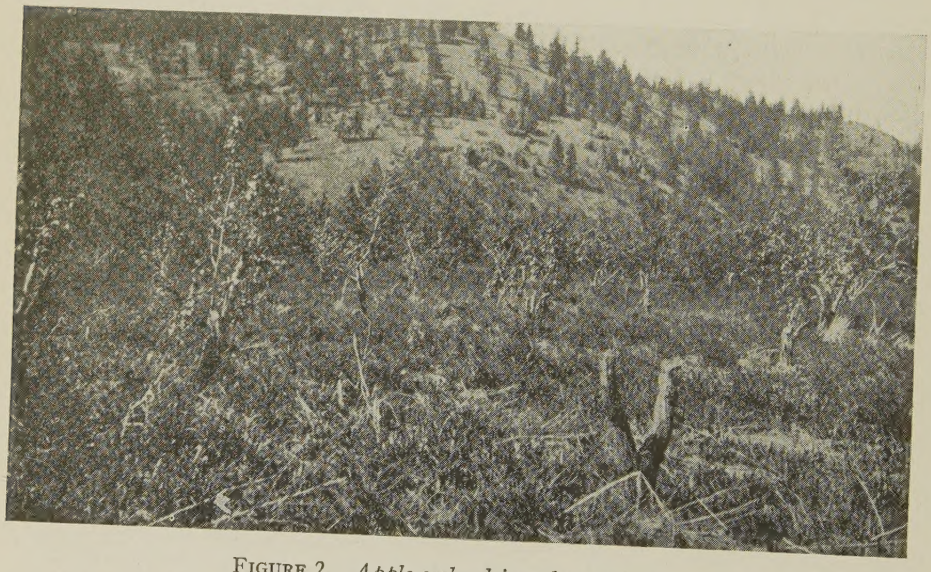

FIGURE 2. *Apple orchard in a degraded phase.*

SOIL DESCRIPTION

The fertile and unproductive soils occur in one soil type, a heavy clay profile known as Glenmore clay; that is, both phases belong to the same textural classification.

The Glenmore series has developed under semi-arid conditions. The annual rainfall is about 12 inches, and the average relative humidity about 70. The average monthly temperature varies from 25 to 67 degrees.

The healthy, productive phase, which will be called "normal," is found on the well drained slopes. Samples for analyses were selected from a virgin profile from an area supporting a normal growth of native vegetation. The profile description is as follows:—

A horizon: 7 inches in thickness, a medium brown coloured clay; it tends to form clods which pulverize easily to form a crumb structure; it is a well flocculated soil, and although heavy, it works into a good tilth with intelligent cultivation.

B horizon: 18 inches in thickness, a medium brown coloured clay; it has a definite jointed columnar structure; the columns are friable and break down to a nut structure; scattered throughout the horizon are calcium carbonate concretions.

C horizon: a light grey brown clay; it is of a laminated or plated structure, in which the plates are an eighth to a quarter of an inch in thickness; each plate is separated from the next by a thin silt layer; this horizon contains calcium carbonate concretions and in many instances pockets of salt crystals; the structure and texture of this horizon is such that gravitational and ground water movements are restricted.

The mechanical analyses of these horizons are as follows:—

Horizon	Total Colloids	Sand	Silt	Clay
A	81.6%	6.4%	48.0%	45.6%
B	88.0%	2.0%	50.0%	48.0%
C	83.2%	4.8%	26.0%	69.2%

The infertile clay, which will be called "degraded" is found wherever drainage conditions are poor, the largest area being down the centre of the valley floor. However this phase is not limited to the bottom lands only, for patches of degraded clay are to be found extending from the toe of slopes and up the sides for a considerable distance.

The profile of this phase is the same as that of the normal, except that the surface soil is deflocculated, bakes on drying into very hard clods, and is generally difficult to cultivate. The columnar B horizon is less distinct, the tendency being for the columns to be less clearly defined due to the dispersed state of the clay.

The samples for analyses were taken from an abandoned orchard in which tree growth had been completely killed out. The soil in the past has received cultivation and irrigation, but due to its present infertile condition, the land is no longer cropped.

From the above soil profile descriptions, these soils may be classified as chernozem, and from a study of the chemical analyses that follows, may be further classified as saline alkali, solonetz type (*1*).

ANALYTICAL DATA

Soil reaction was determined by the quinhydrone method, using a 2 : 1 ratio of liquid to soil.

TABLE 1.—pH VALUES

Horizon	In water	In N. KCl	Effervescence in HCl
Normal A	7.5	6.5	No
Normal B	7.6	6.9	Strong
Normal C	7.5	7.0	Strong
Degraded A	7.4	6.7	No
Degraded B	7.4	6.7	Strong
Degraded C	7.6	7.1	Strong

The determination of exchangeable bases presented a problem, for there appears to be no exact method when dealing with soils containing appreciable amounts of soluble salts. The method finally adapted is that of Magistad and Burgess (*2*). The soil was first leached with water, and then shaken with a neutral alcoholic solution of 0.1 normal $BaCl_2.2H_2O$ and filtered.

TABLE 2.—EXCHANGEABLE CATIONS (MILLEQUIVALENTS PER 100 GRS. SOIL)

—	Nor. A	Deg. A	Nor. B	Deg. B	Nor. C	Deg. C
Na.	9.2	14.5	11.9	13.3	14.7	25.2
K.	0.5	0.5	0.2	0.2	0.1	0.7
Ca.	14.2	13.6	16.5	13.9	21.2	10.9
Mg.	10.6	16.0	12.3	6.6	13.1	11.0
Total	34.5	44.6	40.9	34.0	49.1	47.8

DISCUSSION

The soil reactions in Table 1 show insufficient difference to account for the variance in fertility. Although both soils show an alkaline reaction in water, the pH values are such that the presence of sodium carbonate in excess would not appear probable. The values when taken in normal KCl indicate a slight degree of unsaturation of the absorbtion complex. When treated with HCl acid, effervescence in both subsoils shows a reserve of free carbonate.

A brief analysis of the water soluble constituents (not tabulated) indicated a saline soil. The normal phase showed a high proportion of magnesium sulphate, while the degraded soil was high in calcium sulphate. Appreciable amounts of sodium chloride was found in the subsoil of both phases.

Table 2, showing the exchangeable cations, presents significant features in a comparison of the normal and the degraded soils. In the normal soil, calcium, magnesium, and sodium increase with depth. The ratio of sodium to calcium, however, remains relatively the same, *i.e.*, 1 : 1.45 of Na : Ca. In the degraded soil calcium decreases, while sodium increases with depth; thus the ratio widens. The ratio of sodium to calcium in the A horizon is 1 : 0.9, while in the C horizon 1 : 0·4 of Na : Ca. This condition is most clearly shown when the bases are expressed as a percentage of the total exchangeable cations.

TABLE 3.—MILLEQUIVALENTS EXPRESSED AS PERCENTAGE OF TOTAL

—	Ca	Mg	Na	K	Total
Nor. A	41.1	30.7	26.6	1.6	100
Nor. B	40.4	30.1	29.1	0.4	100
Nor. C	43.2	26.5	30.1	0.3	100
Deg. A	30.3	36.0	32.5	1.2	100
Deg. B	40.9	19.4	39.2	0.5	100
Deg. C	22.8	23.0	52.7	1.5	100

In comparing the percentage of exchangeable sodium between the normal and the degraded soils, one is struck by the dominance of sodium in the degraded soil. The A horizon contains 5.6% more sodium than the corresponding horizon of the normal phase. This increases to 10.1% in the B horizon and 22.6% in the C horizon.

CONCLUSION

The unproductiveness of the degraded soil is a result of poor drainage which manifests itself in two ways. First, the accumulation of salts in the seepage water has produced an absorbtion complex dominated by sodium. This produces a highly dispersed clay and an undesirable physical structure.

Due to the poor physical structure, the problem of drainage becomes accentuated. The extension of the degraded soil from the bottom lands to the slopes is a result of a normal, well flocculated soil being changed to a dispersed clay. The inferior physical structure prevents the normal drainage on the slopes being effective, so that seepage backs up behind this soil. This seepage, in turn, through its salt content continues the degradation of the soils above.

Second, the actual presence of free water, or a saturated, anaerobic subsoil, is in itself sufficient to cause the killing out of deep rooted vegetation such as tree fruits.

Reclamation will only be possible if adequate drainage is provided; the removal of seepage and subsoil moisture is pre-requisite to the treatment of the soil with flocculative amendments. Where drainage can be provided for the removal of ground water, soil amendments such as gypsum and sulphur with organic remains, will aid in the re-establishment of a flocculated soil structure, essential to a healthy, productive soil.

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Résumé

Examen chimique d'une argile dégradée de Glenmore. R. H. Spilsbury, Ministère de l'Agriculture de la Colombie-Britannique, Kelowna, C.-B.

La faible productivité des sols dégradés est le résultat d'un mauvais égouttement, qui se manifeste de deux façons: D'abord, l'accumulation des sels dans l'eau d'infiltration a produit une concentration où le sodium domine. Il en résulte une argile très dispersée et une pauvre structure physique, qui complique le problème de l'égouttement. Cette transformation d'une argile, autrefois normale et bien coagulée, en une argile dispersée, explique pourquoi la dégradation du sol remonte des terres de fond aux pentes. La structure physique intérieure entrave l'égouttement normal sur les pentes, et l'eau d'infiltration remonte derrière ces sols, provoquant, par sa haute teneur en sels, la dégradation des couches supérieures.

En deuxième lieu, la présence d'eau libre, causant un état saturé, anaérobique du sous-sol, est par elle-même suffisante pour détruire les végétaux profondément enracinés, comme les arbres fruitiers. La remise de ces sols en état de culture n'est possible qu'avec de bons moyens d'égouttement. Avant de traiter les sols au moyen d'amendements coagulants, il faut pourvoir à l'enlèvement de l'eau d'infiltration et de l'humidité du sous-sol. Lorsqu'on peut drainer pour enlever l'eau du sol, les amendements comme le plâtre et le soufre, avec des résidus organiques, aideront à rétablir la coagulation qui est indispensable pour que le sol soit dans un état sain et productif.

FERTILIZERS FOR THE BLACK AND GRAY SOILS[1] OF CENTRAL ALBERTA

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Before discussing the question of fertilizers for the black and gray soils of central Alberta it might be well to present a brief statement showing the extent and differences in the soils of these two belts.

The black soils are generally well settled and quite largely cultivated, whereas the gray soils are but sparsely settled and slightly cultivated.

The black soils in Alberta comprise somewhat over 8 million acres, whereas the gray soils are in excess of 100 million acres. The black soils are prairie soils with a high content of organic matter (8 to 15%) and well supplied with total plant foods. The gray soils are wooded soils low in organic matter as well as phosphorus. These gray soils are severely leached and possess an undesirable physical condition as compared with the black soils.

Thus the black soils might be designated as initially very fertile and the gray soils relatively infertile. These conditions are well borne out by the crop yields obtained from the two soil areas, despite the fact that the climatic and rainfall conditions are in general similar.

Since 1928 rather extensive fertilizer experiments have been conducted, both on the University plots and in co-operation with farmers. A brief summary of the results will be sufficient to set out the fertilizer problems of these two vast soil areas in Alberta.

FERTILIZERS FOR THE BLACK SOILS

The yields for the grain crops obtained from the black soil on the University farm are reported in Table 1. These plots were in their virgin condition as recently as 1921. They were first cropped in 1923, and since then have produced 9 crops. None of the plots were fertilized prior to 1931. Fertilizers have been applied annually for the past 4 years with the results shown in Table 1.

TABLE 1.—GRAIN YIELDS FROM SOILS EXPERIMENTAL PLOTS.
EDMONTON (BLACK CLAY LOAM)
Bushels per acre

Treatment	Wheat		Oats	
	Yield	Increase	Yield	Increase
Check	37.0	—	65.0	—
N	37.5	0.5	64.7	−0.3
P	42.6	5.6	72.5	7.5
NP	42.9	5.9	72.2	7.2
NPK	45.7	8.7	70.6	5.6

[1] Paper delivered before a joint session of The Western Canadian Society of Agronomy at the Soils Group of the C.S.T.A. at the University of Alberta, Edmonton, June 27, 1935.
[2] Professor of Soils.

From this table a few important facts may be pointed out.

1. The average yield of 37.0 bushels of wheat and 65.0 bushels of oats from the unfertilized plots indicates soil in a high state of natural fertility.

2. There has been little, if any, increase from the application of a fertilizer containing only nitrogen.

3. There have been considerable increases, especially for the wheat crops, for any and all fertilizers containing phosphorus.

4. Potash has slightly increased the wheat yields but has been useless on the oats.

In addition it might be worth while to mention that the time necessary to mature the grain crops, as influenced by the use of fertilizers, has varied from one or two days to as much as ten days depending somewhat on the season. The application of phosphorus has shortened the time necessary for maturity, whereas the application of nitrogen alone has had no effect. The plots receiving potash in addition to phosphorus have in general ripened earliest.

The application of fertilizers to the hay crops has shown increases varying approximately $\frac{1}{4}$ to $\frac{1}{2}$ ton per cutting. In the case of legumes the fertilizers containing phosphorus have been most effective as was the case with the grains. However, nitrogen was effective in the cases of the older stands of the grasses.

In certain areas of the black soils, especially where they have been cropped for longer periods, as much as 35 per cent increases have been obtained from the use of the phosphate fertilizers. As an example of this condition the farm of Mr. J. H. McLaughlin of Spruce Grove offers a good example. As an average Mr. McLaughlin obtains approximately 15 bushels of wheat increase for the use of phosphates on his fallow; that is, the untreated land yields about 25 to 30 bushels whereas the fertilized land yields 40 to 45 bushels. The increases for fertilizers on the second and third crop after fallow were about one half as great as for the fallow.

The above results quite clearly indicate that the most effective fertilizer for the black soils is one supplying phosphorus. This is entirely a different picture than the one shown for the gray wooded soils.

Before proceeding to the discussion of the fertilizers for the wooded soils it should be pointed out that the black soils of Alberta at present constitute one of the areas in which the use of fertilizers is general.

FERTILIZERS FOR THE GRAY SOILS

The gray wooded soils of Alberta are only sparsely settled at present. They constitute a vast area in which much of the future settlement must take place. They are initially low in fertility as indicated by the fact that the organic matter content is only about half that of the black soils, and the phosphorus content about 60%. In addition they usually possess an undesirable tendency to bake. The above facts indicate that the management of these soils, together with the proper use of fertilizers, constitute a much more serious problem than for the black soils. That these soils

can, by special management and the use of proper crops and fertilizers, be made to yield satisfactory crops has been definitely proven by experiments on the University plots as well as by numerous co-operative experiments.

A brief summary of the results from the Breton experimental field will serve to point out the great necessity for growing legumes, and the use of fertilizers, and furthermore, that following such practices the crop yields become of the same order as those obtained from the black soils.

The experimental field had been cropped for at least ten years, and had reached a stage where the crop yields were decidedly unsatisfactory. It was laid down to plots and some fertilizers applied in 1929. The major part of the treatment was applied in 1930, and the remainder of the field received fertilizers in 1931 and each year since.

The results obtained from the main rotation experiments for the three years (1932–34) are reported in Table 2.

TABLE 2.—CROP YIELDS FROM MAIN ROTATION. BRETON EXPERIMENTAL FIELD (THREE YEAR AVERAGES 1932 TO 1934)

Plot	Treatment*	Yield per acre				Increases			
		Clover Lbs. per acre	Wheat Bus. per acre	Oats Bus. per acre	Barley Bus.. per acre	Clover Lbs. per acre	Wheat Bus. per acre	Oats Bus. per acre	Barley Bus. per acre
1, 5, 11	None	1680	18.4	34.5	16.1	—	—	—	—
2	M	2800	24.3	45.1	19.1	1120	5.9	10.6	3.8
3	NPK	5535	45.2	49.9	20.4	3855	26.8	15.4	4.3
4	N	4430	34.8	64.8	27.0	2750	16.4	30.3	10.9
6	L	3030	24.8	40.9	16.1	1350	6.4	6.4	0.0
7	LP	4570	33.0	47.8	19.5	2890	14.6	13.3	3.4
8	P	4015	27.5	42.3	15.7	2335	9.1	7.8	−0.4
9	MP	3875	39.2	54.1	27.7	2195	20.8	19.6	11.6
10	NP	5515	41.9	59.5	25.5	3935	23.5	25.0	9.4

*The manure was applied once in three years, the lime once in four years and all other fertilizers annually at the following rates per acre:—

Plot 1, 5, 11 —None.
Plot 2 M —Manure 22 tons.
Plot 3 NPK —Ammonium phosphate (16–20) 60 lbs., potash 30 lbs.
Plot 4 N —Ammonium sulphate 60 lbs.
Plot 6 L —Lime (marl) one ton.
Plot 7 LP —Lime one ton, triple superphosphate 50 lbs.
Plot 8 P —Triple superphosphate 50 lbs.
Plot 9 MP —Manure 22 tons, triple superphosphate 50 lbs.
Plot 10 NP —Ammonium phosphate (16–20) 60 lbs.

Additional results from the use of fertilizers on such crops as alfalfa, Altaswede and alsike clovers showed yields from the check plots varying from about a thousand pounds to about 1400 pounds per acre, whereas the better fertilized plots yielded as much as $2\frac{1}{4}$ tons.

Co-operative experiments conducted on various farms gave results of the same nature and magnitude as those reported from the Breton field.

The most important points brought out by these experiments are:—

1. Decided increases for clovers were obtained from all fertilizers. Most of the fertilizers doubled or in some cases tripled the yields obtained from the check plots. The smallest increases were from the manure alone and the lime alone, each of which was over a half ton. All other fertilizers gave increases varying from approximately one ton to two tons.

2. The wheat crop (first after the clovers) showed greater increases for the fertilizers than did the oats or barley which were the second and third crops respectively after the clovers. The yields from the check plots averaged 18.4 bushels, whereas some of the fertilizers more than doubled this yield. The increase for manure alone was 5.9 bushels, whereas the increase from the complete fertilizer was 26.8 bushels. Five of the fertilizer treatments gave increases varying from approximately 15 bushels to approximately 27 bushels.

3. The oat crop (second after clovers) still showed the effect of the clovers. The average yield from the check plots was 34.5 bushels and from the highest yielding fertilized plot 64.8 bushels. Five of the fertilizer treatments gave increases varying from approximately 13 bushels to 30 bushels. The increases were in general lower than for the preceding wheat crop.

4. The barley crop (third after clovers) showed increases from the fertilizers, but of a much smaller magnitude than for the first and second crops after the clovers. In only three cases were the increases greater than about 4 bushels.

5. The best fertilizers for both the clovers and the grains were those carrying a high content of nitrogen (See plots 3, 4, 9 and 10). The fertilizer carrying only nitrogen was very effective in the production of grains for the second and third year after the clovers. However, greater returns were obtained in the case of the clover and the first crop after clover when the fertilizer contained phosphorus in addition to the nitrogen.

6. The plowing under of clovers alone gave fairly good responses as indicated by the fact that the clover alone gave yields of 18.4 bushels of wheat, whereas the yields of wheat were only 11.5 bushels where clover had not been grown on the land. Plowing under of clovers was much more effective when in conjunction with the use of fertilizers. The use of fertilizers alone, while giving increases in some cases of the order of about 9 bushels of wheat, was much less effective than when used in conjunction with clovers. The use of fertilizer alone or of clovers alone was not adequate for the production of maximum crop yields. The practice of plowing under of clovers in conjunction with the use of fertilizers doubled the productive power of the wooded soils, and the value of clovers was of the same degree as that of the fertilizers. It may not be necessary to plow under the entire clover crop, and in cases where the farmer needs the clovers for hay the crop might well be cut and harvested and the land immediately plowed. This practice would be of decided benefit even though the results may not be quite as great as when the clover crop had been plowed under.

7. As a general statement covering all grains and legume crops the results might be expressed as follows: The increases in yields were from 2 to 4 times as great for both the fertilizers and the clovers when used conjointly as when used alone.

8. The practice of growing legumes and using fertilizers on these wooded soils, however, implies that some livestock must be kept in order to ensure a home market for the extra hay.

In connection with this suggested system of management the farmer might well consider the possibility of producing clover seed as an important item in the income from these soils. The production of seed from the alsike and Altaswede clovers has been very satisfactory in these experiments.

ERRATUM

The material on this page should be inserted in the January, 1936, issue of *Scientific Agriculture* following page 240 in the article "Fertilizers for the Black and Gray Soils of Central Alberta," by F. A. Wyatt.

THE FERTILIZING VALUE OF SULPHATE IN NATURAL "ALKALI" FOR GRAY WOODED SOILS[1]

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Fertilizer experiments carried out during the past few years have shown that the leached, gray, wooded soils, or podsols, of Alberta are deficient in sulphur.

When a number of Alberta soils from different parts of the province were analysed for total sulphur, it was found that a sample of gray podsol-like soil contained the least sulphur (*7*). The results of experiments to measure the rate at which sulphur is oxidized to sulphate in Alberta soils, and to determine the effect of sulphur treatment of soil for the control of common scab of potatoes, were published several years ago (*2*, *10*). The treated field plots at Breton were seeded down to red clover in 1932, and it was observed that where sulphur had been applied at the rate of one ton per acre in 1930, the growth of red clover was greater than on adjacent soil where it had not been applied. However, the two-ton rate of sulphur application had apparently made the soil too acid for satisfactory growth of clover. Other unpublished experiments conducted by the University of Alberta Soils Department at Fallis, Alberta, during the past three seasons, have shown that spring applications of sulphur or gypsum (calcium sulphate) to clovers at the rate of about one hundred pounds per acre produce very marked increases in clover growth.

In view of the fact that the "alkali" found in numerous lake and slough beds of the prairie region of the prairie provinces consists mainly of sulphates it was thought that it might be worth while to test the fertilizing value of these "alkali" salts on the gray, wooded soils.

Pot culture experiments were started in the greenhouse in the fall of 1934, and field tests were carried out in 1935. The result of field plot tests at three fairly widely separated points in the gray wooded soil belt west of Edmonton are reported in Table 1. The "alkali," gypsum, and

TABLE 1.—FIELD PLOT EXPERIMENTS WITH "ALKALI" AND OTHER FERTILIZERS APPLIED AS TOP DRESSINGS TO CLOVERS IN 1935

Treatment	Fallis—Red clover, fert. appl. May 27, clover cut July 16, period 50 days		Carrot Creek—Alsike, fert. appl. June 6, clover cut July 22, period 46 days		Edson—Red clover, fert. appl. June 7, clover cut July 23, period 46 days	
	Dry hay per acre		Dry hay per acre		Dry hay per acre	
	Yield	Gain	Yield	Gain	Yield	Gain
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Check	1045	—	1710	—	1500	—
"Alkali"	3975	2930	3255	1545	4195	2695
Ammonium sulphate	3980	2935	4240	2530	4190	2690
Gypsum	3090*	2045*	2990	1280	4250	2750

*Gypsum was applied June 8th, in this case, and the clover was cut 38 days later.

[1] Contribution from the Department of Soils, University of Alberta, Canada.
[2] Professor of Soils.

ammonium sulphate were each applied at the rate of about one hundred pounds per acre, and each produced very marked increases in growth of clover. The increases in yield from the use of "alkali" varied from about three-quarters of a ton to one and one-half tons of dry hay per acre. Furthermore, previous experiments with sulphur and gypsum showed a residual effect on the second season's crop about as great as in the season of application, and one may expect similar results with the natural "alkali."

The "alkali" salt used in the field plot experiments was almost pure sodium sulphate from Whitehorse Lake, Palo, Saskatchewan. Several investigators have shown that the "alkali" deposits of Alberta and Saskatchewan consist mainly of mixtures of sodium, magnesium, and calcium sulphates, with sodium sulphate predominating (*1*, *4*, *5*). There is comparatively little chloride or carbonate present. In pot culture experiments a natural mixture of Alberta "alkali" gave quite as large an increase in growth of clover as pure sodium sulphate.

Calcium compounds are sometimes preferable to sodium compounds as fertilizers, and on this account calcium sulphate (gypsum) might be considered preferable to sodium sulphate. However, sodium nitrate is used in many countries as a standard fertilizer, and the important deposits of gypsum in Alberta are not readily accessible.

The "alkali" would not supply phosphorus or potassium to the soil (except perhaps in very small quantities), but would greatly increase the soil's supply of nitrogen by stimulating the growth of the nitrogen-fixing bacteria attached to the roots of the clover plants.

In its natural state in prairie lake beds the sodium sulphate (Glauber's salt) contains about fifty-six per cent of water of crystallization. This water is removed when the salt is purified and prepared for use in pulp and paper mills, nickel refineries, and other industries. The dehydrated salt is sometimes prepared in the form of fine granules, which would run freely through fertilizer drills. However, it would not be necessary to purify the natural salt mixture in any way for fertilizer purposes, as the magnesium and calcium sulphate would be quite as beneficial as sodium sulphate, and the small amount of sodium carbonate present would tend to neutralize the natural acidity of the gray soils. But, the transportation charges on the natural "alkali" would be greater on account of its high water of crystallization content, and the material would be more difficult to apply than the processed product.

There are many very large deposits of "alkali" in Alberta and Saskatchewan and the locations and descriptions of the more important deposits are given in a publication of the Canada Department of Mines (*1*). These deposits occur mainly in the brown and dark brown soil belts where there are also numerous smaller deposits.

The gray, wooded soil belt is the largest of the great soil zones of Alberta, but it is still rather sparsely settled. The locations of the major soil belts are shown on a sketch map of Alberta in an earlier publication (*6*). It has been shown repeatedly that the production of clovers and other legumes and the use of fertilizers will very greatly increase the productivity of the rather infertile gray, wooded soils (*6*, *8*, *9*). Soils of a somewhat similar nature occur also in northern Saskatchewan and Manitoba.

The effect of the "alkali" on crops other than legumes has not been satisfactorily tested. When applied to a mixture consisting of grasses and some clover at Fallis last spring its effect on the grass was not observed as soon as that of ammonium sulphate, but it did increase the growth of the grasses later on. In the sulphur-deficient soil areas of Oregon, legumes gave marked responses to sulphur fertilizers, whereas moderate or very small increases were obtained with other crops (*3*). However, it has frequently been observed that if wheat or another cereal follows a good crop of clover and is fertilized with ammonium sulphate or ammonium phosphate (containing sulphate) or certain other fertilizers, the grain yield is increased far more by the combination of fertilizer and clover than by the fertilizer alone (*6*, *8*, *9*).

The beneficial effect of various commercial fertilizers containing sulphate is sometimes due in a large measure to this constituent. Sulphur deficient soils may not be as uncommon in Canada as they are generally considered to be, and it may be desirable to conduct more fertilizer experiments with sulphur or sulphur compounds, particularly on leached soils or podsols.

SUMMARY

(1) The gray, wooded soils of Alberta's largest soil zone are deficient in sulphur.

(2) In the lake and slough beds of the prairie region of Alberta and Saskatchewan there are many very large deposits of "alkali" as well as numerous smaller deposits. This "alkali" consists mainly of sulphate salts.

(3) In field plot tests on gray, wooded soil, this "alkali," applied at the rate of about one hundred pounds per acre, produced very large increases in growth of red and alsike clovers.

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Résumé

Valeur fertilisante du sulfate dans l'"Alkali" naturel pour les sols gris boisés.
Par J. D. Newton, Université de l'Alberta, Edmonton.

Les sols gris boisés de la plus grande zone des sols de l'Alberta manquent de soufre. Dans les lits des lacs et des marécages de la région des prairies de l'Alberta et de la Saskatchewan il y a un grand nombre de gros dépôts d'"alkalis" ainsi que de nombreux dépôts de moindre importance. Cet "alkali" consiste surtout en sels de sulfate. Dans les essais de culture sur ces sols gris boisés, cet "alkali", appliqué à raison de cent livres environ par acre, a grandement stimulé la végétation des trèfles rouge et d'alsike.

COMPOSITION AND FERTILIZATION OF ALBERTA PEATS[1]

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It has been estimated that peat or "muskeg" areas cover at least five million acres in the province of Alberta. These peat areas occur mainly in the gray wooded soil belt, but there are numerous minor areas in the black soil belt. The location of these soil belts or zones is shown in a previous publication (*7*). Most of the Alberta peats studied have been classified broadly as "highmoor" or "moss" peats. Many small areas have already been brought under cultivation.

Some references to studies of Canadian peats were given in a previous paper (*3*), and other studies were recently reported by Shutt and Wright (*6*).

Composition of Alberta peats

The chemical composition of some typical Alberta peats is shown in Table 1. The composition and description of these samples was given and discussed in a previous paper (*3*), but the potassium content of the samples was not then included.

The potassium content of certain samples is very low, as shown in Table 1, indicating a need of potash fertilizers. It can be calculated from available potassium per cent figures, when the low specific gravity of the peat is considered, that some Alberta peats contain only enough potassium in the upper two or three feet for ten or fifteen good crops of grain provided all of it could be made available. According to Brüne (*2*) a large proportion of the total potassium in peats is absorbed by growing crops, after which yields tend to decrease rapidly unless potassium fertilizers are applied.

Pot culture experiments

A quantity of surface and subsurface Stonyplain high-lime peat was obtained, broken up, but not ground finely, thoroughly mixed and used to fill a series of one-gallon glazed crocks with holes to provide for drainage.

Fertilizers were added at the following rates: nitrogen at the rate of one and one-fifth grams of sodium nitrate per crock, phosphorus at the rate of three and one-tenth grams of triple super phosphate, potassium at the rate of one gram potassium sulphate, lime at the rate of twenty-five grams calcium carbonate, and mixed farm manure at the rate of one hundred and fifty grams of moist manure per crock. These fertilizers were mixed with the peat in the crocks, Victory oats were planted, and the crocks watered as often as necessary to maintain a good supply of moisture.

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[1] Paper delivered before a joint session of the Western Canadian Society of Agronomy and the Soils Group of the C.S.T.A. at the University of Alberta, Edmonton, June 27, 1935.

[2] Professor of Soils.

TABLE 1.—COMPOSITION OF PEAT SAMPLES (WATER-FREE BASIS)

Peat samples		Ash	Cellulose (minus ash)	Lignin (minus ash)	Cellulose + lignin + ash	Ether extract	Nitrogen N	Phosphorus P_2O_5	Potassium K_2O	Calcium CaO	Reaction pH
		%	%	%	%	%	%	%	%	%	%
Carnwood,	1st depth	4.1	26.0	35.6	65.7	0.7	1.07	0.13	0.23	0.90	4.0
Winterburn,	1st depth	7.6	33.5	38.6	79.7	1.1	1.02	0.11	0.06	3.43	7.0–7.5
Winterburn,	2nd depth	10.4	5.1	44.1	59.6	0.6	2.54	0.18	0.05	3.29	7.0–7.5
Winterburn,	3rd depth	37.5	0.0	42.1	79.6	0.6	1.75	0.27	0.29	1.07	6.5
Spruce Grove,	1st depth	14.0	46.9	20.1	81.0	1.1	0.46	0.10	0.41	1.19	4.0
Spruce Grove,	2nd depth	20.1	30.2	25.9	76.2	1.0	0.79	0.13	0.17	4.61	7.0–7.5
Stonyplain,	1st depth	21.1	21.1	24.6	66.8	0.5	0.89	0.13	0.08	4.75	7.0–7.5
Stonyplain,	2nd depth	8.1	11.8	48.9	68.8	0.9	1.74	0.21	0.05	3.47	5.5
Vimy,	1st depth		54.5*								
Vimy,	2nd depth		11.0*								

*Including ash.

Growth of oats in Stonyplain high-lime peat treated with different fertilizers is shown in Figures 1 and 2, and Table 2.

TABLE 2.—PLATE COUNTS OF BACTERIA AND GROWTH OF OATS IN STONYPLAIN PEAT TREATED WITH FERTILIZERS (POT CULTURE EXPERIMENT)

Treatment, Jan. 20	Bacteria, millions per gm.		Oat crop, dry wt.	
	April 6	April 16	June 19, duplicates	
Control	5.0	7.0	16.0 gm.	18.5 gm.
Lime ($CaCO_3$)	6.2	5.4	8.0 gm.	9.5 gm.
N ($NaNO_3$)	—	2.6	9.0 gm.	9.5 gm.
P (Super)	1.4	3.8	5.5 gm.	5.0 gm.
K (K_2SO_4)	1.8	4.2	10.5 gm.	12.5 gm.
Complete (N + P + K)	19.5	26.1	68.0 gm.	59.0 gm.
Complete + lime	22.6	20.9	57.0 gm.	43.5 gm.
Manure	6.4	11.4	37.5 gm.	40.5 gm.
June			October duplicates	
Control			1.8 gm.	1.8 gm.
P + K			2.8 gm.	2.6 gm.
N + P			14.5 gm.	16.3 gm.
N + P + K			22.0 gm.	17.7 gm.

FIGURE 1. Growth of oats in Stonyplain peat as influenced by different fertilizers. Left to right: (1) Control; (2) "Complete" plus lime; (3) Phosphorus; (4) Manure; (5) Nitrogen; (6) Potassium; (7) "Complete"; (8) Lime.

In this experiment it was interesting to observe that the addition of single fertilizers actually depressed the yields. The reason for this small depression is not definitely known, but it may be due to an unbalanced supply of nutrients. The complete fertilizer, containing nitrogen, phosphorus, and potassium, produced the greatest growth. Lime was of no benefit when added to complete fertilizer. If anything, it was rather harmful as the Stonyplain peat is naturally very high in lime. Farmyard manure alone was very beneficial as a fertilizer for this peat. A combination of phosphorus and potassium fertilizers was only slightly beneficial, but the combination of nitrogen and phosphorus fertilizers was decidedly beneficial. It is interesting to compare these results with the results obtained by Alway (*1*) who observed that the high-lime peats of Minnesota rarely need a nitrogen fertilizer.

FIGURE 2. Growth of oats in Stonyplain peat as influenced by different fertilizers. Left to right: (1 and 2) control; (3 and 4) phosphorus and potassium; (5 and 6) nitrogen and phosphorus; (7 and 8) "complete."

In the experiment reported in Table 2, representative samples of peat were taken from the crocks twice during the period of crop growth and the numbers of bacteria present were determined by the plate count method. It will be observed (Table 2) that the growth of oats was roughly proportional to the bacterial numbers in the peat. This indicates that the fertilizer salts brought about some decomposition of the peat organic matter, and were not simply held unchanged in the peat. It seems clear that these rather raw or undecomposed western peats can be decomposed to some extent rather readily under favourable conditions.

It is interesting to contrast these large increases in bacterial numbers, produced by the addition of certain mineral fertilizers to peat, with the comparatively small or insignificant changes in bacterial numbers produced by the addition of the same quantities of these fertilizers to similar crocks of mineral soils, as shown in Table 3. As is well known, however, the addition of readily decomposable organic matter to mineral soil produces a large increase in bacterial numbers, and this effect is shown also in Table 3, in the crocks of mineral soil to which ground alfalfa was added.

Another somewhat similar pot culture experiment with Carnwood acid peat and Stonyplain high-lime peat is reported in Table 4. Fertilizers were added at the following rates: nitrogen at the rate of one gram ammonium sulphate per crock, phosphorus at the rate of two grams of triple superphosphate, potassium at the rate of one gram potassium sulphate, lime at the rate of twenty-five grams calcium carbonate, and mixed farm

TABLE 3.—PLATE COUNTS OF BACTERIA IN MINERAL SOILS TREATED WITH DIFFERENT FERTILIZERS (POT CULTURE EXPERIMENT)

Treatment, October 20	Edmonton black loam, millions per gram			Breton grey loam, millions per gram		
	Dec. 30	Feb. 6	April 9	Dec. 2	Jan. 21	May 2
Control	9.3	10.1	10.8	18.1	6.6	8.6
N $(NH_4)_2SO_4$	16.2	7.8	19.4	21.0	8.7	12.4
P (Super)	15.8	9.0	15.5	21.4	7.7	6.3
K (K_2SO_4)	11.5	8.1	11.8	15.6	7.1	10.8
N + P	15.0	10.3	16.3	11.9	7.1	8.9
N + P + K	12.8	7.2	17.5	14.5	8.7	16.1
October 20	Jan. 8		April 16	Dec. 11	Jan. 28	May 1
Alfalfa	29.1	—	51.8	65.2	47.9	41.3
Alfalfa + N + P	39.3	—	32.3	77.5	41.8	39.6
Alfalfa + N + P + K	18.1	—	40.1	60.2	48.4	43.4

manure at the rate of one hundred and fifty grams of moist manure per crock. Lime was used together with different fertilizers in some of the pots, as shown in Table 4, mainly with the object of determining its effect on the acid peat.

TABLE 4.—NITRATE NITROGEN AND GROWTH OF OATS IN STONYPLAIN HIGH-LIME PEAT' AND CARNWOOD ACID PEAT TREATED WITH DIFFERENT FERTILIZERS. (POT CULTURE EXPERIMENT)

Treatment, Nov. 21	Nitrate nitrogen (parts per million)						Oats (dry wt.)	
	Jan. 26	Feb. 9	Feb. 23	Mar. 9	Mar. 23	April 6	April 22, duplicates	
CARNWOOD ACID PEAT								
Control	Trace		Trace		Trace		4.2 gm.	4.9 gm.
N $(NH_4)_2SO_4$	10		Trace		Trace		6.8 gm.	—
P (Super)	Trace		Trace		Trace		9.2 gm.	8.4 gm.
K (K_2SO_4)	Trace		Trace		Trace		8.5 gm.	9.0 gm.
N + P	Trace		Trace		Trace		3.7 gm.	10.0 gm.
N + P + K	Trace		Trace		Trace		8.2 gm.	11.9 gm.
Lime $(CaCO_3)$	Trace		Trace		Trace		9.0 gm.	9.4 gm.
Lime + N	18		19		Trace		16.5 gm.	15.5 gm.
Lime + N + P	15		48		16		9.5 gm.	11.5 gm.
Lime + N + P + K	4		14		Trace		15.8 gm.	20.5 gm.
Manure	Trace		Trace		Trace		10.0 gm.	9.5 gm.
STONYPLAIN HIGH-LIME PEAT								
Control		Trace		Trace		Trace	5.1 gm.	8.7 gm.
N $(NH_4)_2SO_4$		Trace		Trace		Trace	14.2 gm.	14.2 gm.
P (Super)		Trace		Trace		Trace	9.3 gm.	9.5 gm.
K (K_2SO_4)		Trace		32		Trace	6.5 gm.	8.5 gm.
N + P		13		30		66	20.0 gm.	22.7 gm.
N + P + K		19		30		44	24.2 gm.	25.7 gm.
Lime $(CaCO_3)$		Trace		33		27	11.2 gm.	12.0 gm.
Lime + N		10		21		33	21.5 gm.	20.7 gm.
Lime + N + P		8		20		24	23.5 gm.	26.0 gm.
Lime + N + P + K		8		14		12	22.5 gm.	24.3 gm.
Manure		9		57		33	22.2 gm.	20.0 gm.

The oat crop yields were generally smaller in the case of the acid peat, even where lime was applied; and the duplicates less regular than in the case of the high-lime peat. The combination of nitrogen and phosphorus fertilizers produced about as high a yield of oats on the high-lime peat in this experiment as the combination of these fertilizers with a potassium fertilizer.

The nitrate content of the peat in the crocks was determined three times during the period of crop growth. In the case of Carnwood acid peat nitrate did not accumulate where lime was not applied, according to these determinations, except in one case. Where lime and nitrogen (non-nitrate) fertilizers were applied, nitrate did accumulate. In the case of the Stonyplain high-lime peat, nitrate accumulated in nearly every culture to which nitrogen (non-nitrate) fertilizer was added. In two cases (lime alone and potassium sulphate alone) nitrate accumulated in Stonyplain peat to which no nitrogenous fertilizer had been applied, and in these cases the peat's own nitrogen must have been nitrified. Other experiments with Alberta peats have given similar results, and it is interesting to observe that the nitrate has accumulated in spite of the low nitrogen content, or high carbon to nitrogen ratio of the peat. According to Russell (*5*) and others the nitrogen of soil organic matter can appear as nitrate only if it exceeds a certain critical amount relative to carbon, and when the proportion of carbon is greater, the nitrogen remains as complex protein. This critical ratio is usually twelve or less of carbon to one of nitrogen, but in some of the Alberta peats studied, nitrates accumulated in spite of a wider carbon to nitrogen ratio. However, this may be explained by differences in availability of carbon and nitrogen, for, as pointed out by Norman (*4*), if a portion of the carbon is relatively unavailable, the true ratio may be considerably narrower.

There was considerable correlation between nitrate accumulation and yield, as shown in Table 4. This indicates that crops grown on these peats, like crops grown on ordinary mineral soils, obtain their nitrogen mainly in the form of nitrate.

Field trials

The results of several field trials with commercial fertilizers in the vicinity of Edmonton are in general agreement with results obtained in pot culture experiments. The highest yields of oats for greenfeed on high-lime peats were obtained on plots receiving a "complete" fertilizer containing nitrogen, phosphorus and potassium. A combined nitrogen and phosphorus fertilizer was quite beneficial, but nitrogen alone or phosphorus alone was only slightly beneficial.

SUMMARY

1. Some of the Alberta peats studied are deficient in potassium as well as in other elements and essentials of fertility.

2. Different fertilizers applied to Stonyplain high-lime peat, in pot culture experiments, produced the following results: A "complete" fertilizer was most beneficial, a combined nitrogen and phosphorus fertilizer decidedly beneficial, and a combined phosphorus and potassium fertilizer

somewhat beneficial. Nitrogen alone, phosphorus alone or potash alone was but slightly beneficial or actually harmful. Farmyard manure alone was decidedly beneficial. Lime was not beneficial.

3. In the case of Carnwood acid peat the yields were generally lower and less regular, even where lime was applied, than in the case of Stony-plain high-lime peat.

4. Large increases in bacterial numbers were produced by the addition of certain mineral fertilizers to peat soil, whereas comparatively small or insignificant changes were produced by the addition of these fertilizers to mineral soils. Large increases in bacterial numbers were produced by the addition of readily decomposable organic matter to mineral soils.

5. Growth of oats was roughly proportional to bacterial numbers in peat to which different fertilizers were applied.

6. Nitrates did not accumulate in unlimed acid peat under oats (except in one case), but did accumulate in high-lime peat and in acid peat to which lime had been applied.

7. There was considerable correlation between nitrate accumulation and yield.

8. Nitrification of the peat's own nitrogenous organic matter occurred, in spite of the peat's low nitrogen content or high carbon to nitrogen ratio.

9. "Complete" fertilizers gave highest yields of oats for greenfeed in several field trials with various commercial fertilizers in the vicinity of Edmonton.

ACKNOWLEDGMENT

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Résumé

Composition et fertilisation des tourbes de l'Alberta. J. D. Newton, Université d'Alberta, Edmonton, Alberta.

Parmi les tourbes de l'Alberta qui ont été étudiées il en a été trouvé quelques-unes qui étaient pauvres en potasse et qui manquaient généralement des autres éléments de fertilité. Différents engrais chimiques appliqués à une tourbe de Stony-plain riche en calcaire, dans des essais de culture en pot, ont donné les résultats suivants: un engrais "complet" a exercé une action très bienfaisante; un engrais phosphaté et azoté combiné, une action nettement bienfaisante; un engrais phosphaté

et potassique, combiné, une action légèrement bienfaisante; l'azote seul, le phosphore seul ou la potasse seule, n'ont fait que peu de bien quand ils n'ont pas fait de mal. Le fumier de ferme seul a été très avantageux. La chaux n'a fait aucun bien. Sur les tourbes acides de Carnwood les résultats obtenus ont été généralement plus faibles et moins réguliers, même lorsqu'on appliquait de la chaux, que sur les tourbes calcaires de Stonyplain.

L'addition de certains engrais minéraux à la tourbière a provoqué une forte augmentation dans le nombre des bactéries, tandis que l'addition de ces mêmes engrais aux sols minéraux n'a provoqué que des changements relativement faibles ou insignifiants. L'addition aux sols minéraux de matières organiques de décomposition prompte a été suivie par une forte augmentation dans le nombre des bactéries. La végétation de l'avoine a été approximativement proportionnelle au nombre des bactéries dans la tourbe sur laquelle différents engrais avaient été employés. Sauf une exception il ne s'est pas accumulé de nitrates dans la tourbe acide non chaulée, ensemencée d'avoine, mais il y a eu accumulation dans la tourbe riche en calcaires et dans la tourbe acide qui avait été chaulée. On a constaté une corrélation bien marquée entre l'accumulation des nitrates et le rendement. La nitrification de la matière organique azotée de la tourbe s'est produite malgré la faible teneur en azote de la tourbe ou la relation élevée entre le carbone et l'azote. Dans plusieurs essais de grande culture avec différents engrais commerciaux, les engrais "complets" ont donné un magnifique rendement dans la région d'Edmonton.

SOME PEAT BOG PROFILES OF THE LOWER ST. LAWRENCE RIVER AND LAKE ST. JOHN REGIONS IN QUEBEC[1]

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INTRODUCTION AND HISTORICAL BACKGROUND

The purpose of the studies reported in this paper has been to determine the chemical composition and the agricultural possibilities of successive "horizons" or layers within the profiles of representative peat bogs in two of the eastern areas within which major peat occurrences are found in this province. The experimental work and discussion applies fully only to the regions under study. Peat bogs occur widely in Quebec province, but the larger peat areas seem to be grouped in definite regions. The peat profiles discussed here occur in bogs found in two such regions. The Cap St. Ignace (Montmagny) and the Rivière Ouelle (Kamouraska) peat occurrences lie on the clays of the St. Lawrence river valley between 40 and 80 miles east of Quebec city. The Hébertville (Lake St. John), Bagot (Chicoutimi) and Péribonka (Chicoutimi) peat areas lie on the clays of the Lake St. John district more than 150 miles north of Quebec city.

Some of the peat bogs of Eastern Canada have been discussed by Auer (*3*), who, with co-workers, studied many peat areas in the Maritime provinces, Quebec, and Ontario. Auer studied successive significant layers in these bogs from the standpoint of the plants, the remains of which make up the organic matter. Pollen and seed studies were conducted on samples obtained by systematic borings. In all, 28 peat bogs were investigated in this way by Auer, and the Rivière Ouelle bog was included in the number. The profiles of the peat bogs studied were mapped and have been published as Auer found them in 1926, together with charts of sections of these peat bogs showing the vertical distribution and proportional amounts of the pollen species present in samples taken from the different layers he bored through with the Hillier type peat drill used.

In central Canada, because of the lack of coal sources, a lively interest has existed in the possibility of using peat as a coal substitute. This has led to extended investigations during the last 25 years. A formal study of central Canadian peats as fuel was undertaken by the governments of the Dominion of Canada and the Province of Ontario between the years 1918 and 1925. A final report embodying the findings of the appointed committee was published by Haanel in 1925 (*4*). In this voluminous report there is exhaustive discussion of the experimental work done, and numerous tables, diagrams and illustrations are shown. Peat is discussed, and figures are presented showing its value as a fuel source, and some chemical, physical, and botanical data are given. Antedating this committee's work is that of Anrep (*1*, *2*) and of Nystrom and Anrep (*5*). In each of these reports very valuable information is given.

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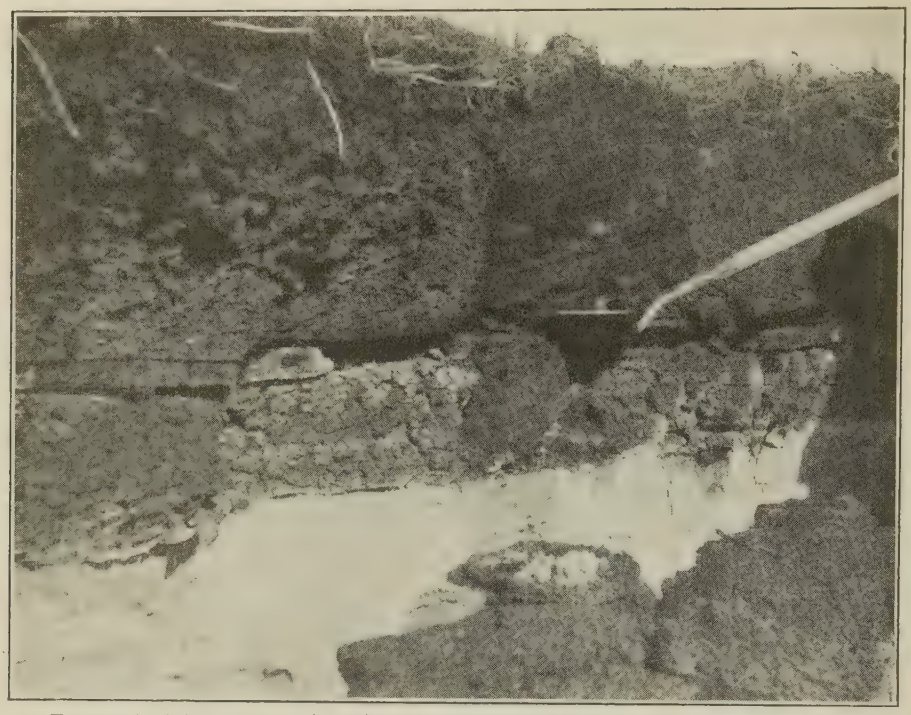

FIGURE 1. The wall of a deep ditch cut through a peat bog, peat above, clay beneath. Note the desiccated state of the peat layer next the clay.

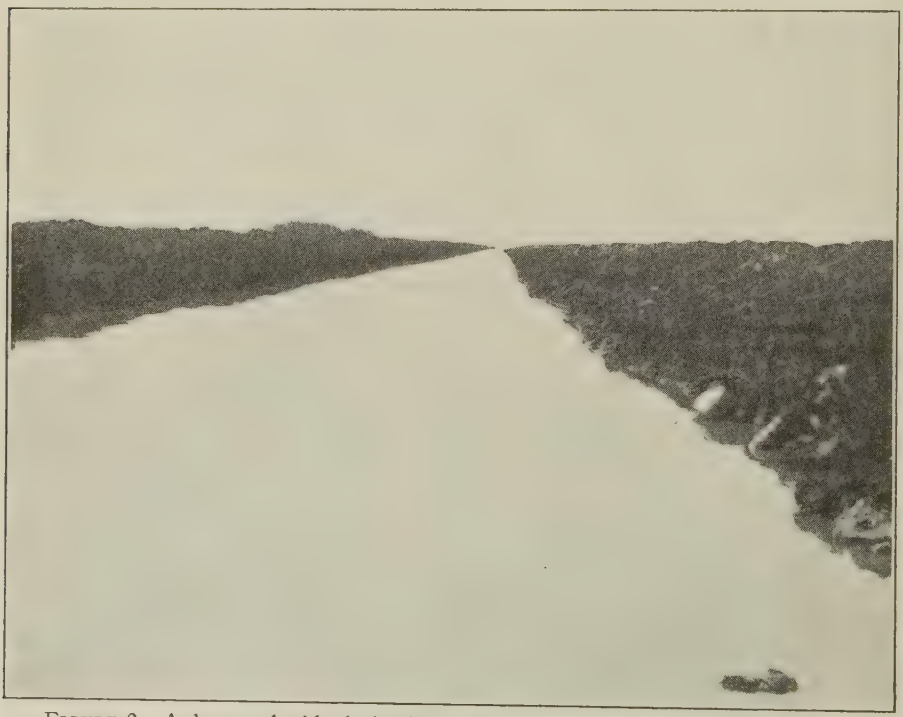

FIGURE 2. A deep and wide drain through the centre of a peat bog. The outlet has not yet been opened.

Photos by A. Sellar.

"HIGH" AND "LOW" BOG PEATS

In the bulletin by Anrep dated 1912 (*1*), there are large plates from photographs illustrating beautifully those plants the remains of which largely make up our Quebec peat occurrences, especially in the "high bog" type, namely:—*Sphagnum fuscum* (sphagnum), *Polytrichum juniperinum* (hair-cap moss), *Chmaedaphne calyculata* (leather leaf), *Vaccinium Oxycoccos* (low-growing cranberry), *Ledum groenlandicum* (Labrador tea), *Kalmia polifolia* (swamp laurel), *K. angustifolia* (sheep laurel), *Sarracenia purpurea* (pitcher plant), *Eriophorum angustifolium* (narrow-leaved cotton grass). "High bogs," conventionally, are those not subjected to floodings; "low bogs" are lower lying and are frequently inundated by water. The conditions of formation of low bogs are usually such as to make their peat richer in mineral matter than that of the high bogs.

The plant species differ greatly in the upper layers of the two types of bog, with mosses, laurels, *Eriophorum* and *Ericaceae* usually dominant in the high bog flora; with the sedges and grasses (*Carex*, *Juncus*, *Scirpus*, etc.), and other water-loving plants and swamp-loving trees the principal sources of organic matter in the low bogs. In low bogs the water which at times flows in and inundates the area is, under our conditions, usually charged with dissolved mineral matter. Thus, our lower-lying peat beds are usually very rich in lime, which comes from their having been soaked repeatedly by the lime-charged waters which have overflowed them. This abundance of lime in low bogs is, of course, particularly evident when the rocks and soils surrounding the peat area are limestone or sandstone rich in lime. Normally, dissolved lime is by far the most abundant mineral constituent of any soil solution, and in these low-lying peats the lime is absorbed and held by the organic absorption complexes, as successive peat layers form and in turn are inundated by incoming water from higher lands.

From these studies and others not reported here, it is certain that the high bog type peats often arise through sheer organic matter accumulation from previously existing low bogs, and conversely, through inundations, the high bog type may change, for a time at least, to the low bog type. In many bogs of good depth, where the peat has been recently cut through by clean-walled, regular ditches, layers 2 feet or more thick may be observed in the middle of the profile in which tree roots and branches exist in quantity. Such layers exist in both the Rivière Ouelle and Bagot occurrences, which today, because of their surface flora and their present elevation, must be classed as high bogs. White birch and swamp alder are the commonest woody remains in these horizons. In both the bogs mentioned above these woody layers are overlain and underlain by layers of moss peat several feet thick.

DRAINAGE AND BURNING AND THEIR EFFECTS

Until some drainage has been effected, Quebec peat areas usually cannot be agriculturally developed; and until they are drained the water content of the surface layers is so great that the usual top burning of the raw, acid, moss peat is not successful, which burning is practised in order that the better decomposed and richer lower layers may be exposed. When humification is satisfactory in the upper foot or so of the peat, it is prob-

able that burning is not good practice. A good field measure of a satisfactory degree of humification is the development of pronounced black colour and a friable, crumbly, non-fibrous structure in the surface peat. Conversely, a yellowish, light brown, greyish or reddish colour in peat as well as fibrous structure, indicate its "raw," non-humified state. Chemical laboratory examination usually confirms these field observations of peat quality, and shows that the mineral content of the dark, friable material is higher than that of the lighter-coloured, fibrous peat, while the acidity of the former is lower and its nitrogen content is higher.

It is very easy to over-do the drainage of peat areas, unless it is desired to burn off the organic matter right down to the clay beneath. Such drastic burning is seldom, if ever, good practice. For, as a rule, in the high bogs the layer next the clay is the best decomposed, the richest in nitrogen and the richest in valuable minerals. When this lowest layer is burned, the clay beneath bakes hard, and there is, in the resulting mineral soil, pronounced deficiency of organic matter. When this lowest one foot or so of black soil is spared and ploughed into the clay, a very desirable soil results.

Burning of the mossy covering at the surface of high bogs is an inevitable step if these bogs are to be brought into agricultural production, but for best results *intelligent burning must be practised.* This can only be done where differences are recognized in the successive layers. It is predictible that in many cases layers lying higher, that is, nearer the surface, in the profiles of peat bogs, will prove better agricultural soils than some of the deeper lying layers. This means that care must be exercised not to dry out too thoroughly the whole mass of peat before burning. It means, further, that farmers must be given guidance in burning, and that they must have well informed advisers.

The question of improvement of our peat areas directly involves the questions of both drainage and burning. Drainage causes tremendous shrinkage in the thickness of peat deposits. In both the Rivière Ouelle and Bagot areas this is extremely noticeable because they have been thoroughly ditched just recently. Auer (*3*) in 1926 found the depth of the Rivière Ouelle deposit to be 17 feet and over at the centre. A wide and deep ditch was driven through the heart of the bog about four years ago and at present (1935), from our observation, the peat has a depth of ten feet or less in that part of the centre of the bog adjacent to the ditch. It is still as deep as it was formerly, at the centre of the bog, one hundred yards or more from the main ditch or the lateral ditches. We have observed similar shrinkage through loss of water in many other peat bogs in Quebec. The peat layers shrink at different rates, the lower-lying, denser layers shrinking less than the looser top layers.

Much difference of opinion exists as to the most effective means of burning off the surface moss. A method that is used on the Rivière Ouelle bog is to plough the surface with a special tractor-drawn plough, the furrow slices being about eight inches deep and eighteen inches broad. These rest slantingly upon each other with an air space beneath part of each. These slices dry out and then can be burned. At the Cap St. Ignace bog one farmer has been surface burning almost every year during the past fifteen years and can never secure deeper burning than about six inches

in the peat as it lies. Once in every twenty years or so there is an abnormally dry, hot summer, when it is asserted that the peat areas will burn much more freely. Each year there is a time in the spring when conditions seem best for burning. This is usually after considerable drying out of the peat has occurred as a result of spring winds and sun, and before new green growth has begun. At best, however, the burning process is slow.

EXPERIMENTAL

The profile observations were made and the samples collected during September and October, 1934. In Table 1 are given typical profile descriptions of the bogs studied.

TABLE 1.—PROFILE DESCRIPTIONS OF SEVERAL PEAT BOGS

Horizon	Depth in inches	Plant source	Colour	Remarks
1. *Riviere Ouelle, at centre, after drainage*				
1	36–144	Chiefly sphagnum	Light brown	Blueberry, laurels, Labrador tea and leather leaf bushes at surface. Raw moss peat. Fibrous.
2	16	Carex sphagnum, white birch roots and branches.	Dark brown streaked with black.	The black streaks contain charcoal. Fairly well decomposed but fibrous.
3	8	Carex and sphagnum	Medium brown	Poorly decomposed peat. Fibrous.
4	3–6	Carex and sphagnum	Medium brown	Fairly well decomposed but fibrous.
5	13	Carex	Yellow	Strong odour of H_2S. Medium decomposition. Non-fibrous.
6	50	Carex and tree branches, trunks and roots.	Dark reddish brown.	Strong odour of H_2S. Non-fibrous. The present water-level is about 2 feet above the bottom of this layer.
7	?		Grey blue	Boulder clay.
2. *Cap St. Ignace, near west end*				
1	24–36	Carex and sphagnum	Reddish brown	Poorly decomposed peat. The surface layer is burned off.
2	24–30	Carex	Dark brown	Poorly decomposed peat.
3	12	Carex with tree remains	Medium brown	Strong odour of H_2S. Poorly decomposed but better than No. 1 and No. 2.
4	6–12	Matted water plants and tree remains.	Black	Strong odour of H_2S. Non-fibrous peat.
5	?		Grey blue	Boulder clay.
3. *Hébertville, north central part of bog*				
1	24–48	Chiefly sphagnum	Light brown	Laurels, Labrador tea and leather leaf, with stunted black spruce trees, at surface. Raw moss peat. Fibrous.
2	24–36	Sphagnum and carex	Reddish brown	Poorly decomposed peat. Fibrous.
3	12–20	Carex	Black	Well decomposed peat. Non-fibrous.
4	?		Grey blue	Boulder clay.
4. *Péribonka, central south-west part of bog*				
1	8–20	Sphagnum and bog plants	Light brown	Labrador tea, laurels, stunted black spruce at surface.
2	12	Chiefly sphagnum, some carex.	Reddish brown	Poorly decomposed peat. Fibrous.
3	8–12	Chiefly sphagnum, some carex.	Dark brown	Poorly decomposed peat.
4	?		Light grey-brown.	Fine sand of low quality.

NOTE.—Another section of this bog is underlain by boulder clay of good quality and here the peat is of somewhat better quality in the lowest layer.

TABLE 1.—PROFILE DESCRIPTIONS OF SEVERAL PEAT BOGS—*Concluded*

Horizon	Depth in inches	Plant source	Colour	Remarks
5. *Bagot*				
1	24–48	Chiefly sphagnum	Light brown	Labrador tea, laurels, *Eriophorum*, etc., grow at the surface, with some stunted black spruce trees.
2	36	Chiefly carex with tree remains.	Dark reddish brown.	Fairly well-decomposed peat. Fibrous.
3	18–24	Carex	Black	Fairly well decomposed peat. Fibrous.
4	?		Grey blue	Boulder clay of high quality.

In Table 2 are given the results of chemical examination of the samples taken from the different horizons of the profiles described in Table 1.

DISCUSSION AND CONCLUSIONS

From inspections of Tables 1 and 2 it will be noted that there are many points of similarity between the bogs whose profiles are under study. In all five bogs, where no burning has been practised, the surface horizon is raw moss peat. Beneath this is found a layer of strongly acid, partly decomposed peat which varies in quality. Beneath this again is found a third main organic layer which is usually well decomposed and quite rich in calcium. The large amount of hydrogen sulphide gas observed in the lower horizons of the Rivière Ouelle and Cap St. Ignace bogs is noteworthy. It indicates the anaerobic state of these water-logged lower peat horizons.

The complete burning away of horizons of well-decomposed peat which possess the richness in nitrogen found in the layers just above the clay in four out of the five bogs is an error. The great amounts of fertility which will be irretrievably lost through such burning are easily calculable. If no other use can be made of these black, well-decomposed layers, they might be used as valuable material to spread on mineral soils near the bogs. However, the element potassium is usually sadly lacking in these black soils. Nitrogen and lime are ordinarily present in sufficient amounts. Phosphoric acid is generally lacking. By making up the deficiencies through use of the proper chemical fertilizers, the general farmer can obtain wonderful results on these black soils. It is again emphasized that this discussion is only of the peat areas studied and reported on here. Hay crops, potatoes and roots are among the crops that will do best. Because of the great amount of nitrogen, grain crops are subject to lodging and other difficulties arising from rank growth and lack of phosphorus and potash. It is probable that seldom will the application of lime be found necessary or profitable on the black organic soil layers of these peat areas.

SUMMARY

Peat profiles of five bogs in two general areas of eastern Quebec have been studied, and representative samples taken from their horizons have been analyzed. In general, the five bogs are at their surfaces of the "high bog" type, but their lowest organic horizons are much the richest in nitrogen

TABLE 2.—CHEMICAL ANALYSES OF SAMPLES TAKEN FROM THE HORIZONS OF SEVERAL PEAT BOG PROFILES*

Approximate area of bog acres	Horizon No.	pH value	Hygroscopic water %	Loss on ignition %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	N %	SO_3 %	P_2O_5 %	CaO %	MgO %	K_2O %	Mn_3O_4 %
1. *Rivière Ouelle Bog*														
6,000	1	3.71	12.51	97.9	0.747	0.104	0.151	0.638	0.25	0.097	—	—	0.052	Trace
	2	3.62	11.53	98.7	0.358	0.046	0.160	0.992	0.48	0.060	0.205	0.282	0.022	Trace
	3	3.65	12.10	99.1	0.175	0.064	0.052	0.857	0.31	0.028	0.113	0.198	0.013	Trace
	4	3.75	12.58	99.0	0.191	0.091	0.079	0.702	0.23	0.028	0.312	0.149	0.017	Trace
	5	4.30	11.29	98.9	0.245	0.120	0.112	1.425	0.43	0.091	0.295	0.038	0.010	Trace
	6	4.48	11.28	98.4	0.219	0.262	0.133	1.395	0.43	0.042	0.427	0.196	0.011	Trace
	7	6.76	1.88	4.52	59.04	5.932	17.596	0.074	0.06	0.032	2.322	2.975	3.330	0.040
2. *Cap St. Ignace Bog*														
500	1	3.49	12.32	98.2	0.935	0.121	0.296	0.742	0.43	0.116	0.127	0.165	0.017	Trace
	2	4.58	13.59	95.4	1.035	0.948	0.438	0.951	0.67	0.086	1.288	0.521	0.043	0.020
	3	4.71	10.89	79.3	17.30	1.598	1.848	1.428	2.49	0.175	0.793	0.584	0.635	0.029
	4	5.05	2.32	5.18	60.91	5.975	14.597	0.121	1.12	0.148	2.176	2.599	3.060	0.070
3. *Hébertville Bog*														
1,200	1	Not analyzed												
	2	3.90	11.12	97.9	1.030	0.379	0.199	1.507	0.30	0.143	0.408	0.063	0.034	0.005
	3	6.20	11.16	92.6	2.625	0.642	0.744	1.808	0.35	0.081	3.930	0.648	0.068	0.007
	4	Not analyzed												
4. *Péribonka Bog*														
8,000	1	Not analyzed												
	2	3.98	10.50	96.5	2.135	0.250	0.312	1.912	0.48	0.270	0.646	0.310	0.038	0.003
	3	5.10	11.18	82.5	12.400	0.736	0.456	1.804	0.40	0.376	0.935	1.378	0.620	0.003
	4	Not analyzed												
5. *Bagot Bog*														
6,000	1	Not analyzed												
	2	3.92	9.81	97.3	1.212	0.151	0.363	1.470	0.44	0.123	0.608	0.321	0.231	0.001
	3	5.98	12.68	87.5	8.380	0.978	1.632	1.519	0.86	0.127	3.400	1.118	0.023	0.019
	4	5.58	1.63	2.18	59.24	6.292	17.679	0.022	0.07	0.166	3.978	2.707	2.940	0.073

*All percentages are expressed on the moisture free basis.

and lime, and the black colour and friable state of these horizons also indicate their well decomposed condition. Potassium and phosphorus are the ordinarily used fertilizer elements most lacking in these lowest horizons. Surface burning of the raw moss peat of these areas is necessary, but "complete" burning is a grave mistake. Normal climatic conditions in these regions prevent such drastic burning at one time and make difficult the necessary removal of the unwanted raw moss peat.

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Résumé

Le profil de quelques tourbières des régions du bas St. Laurent et du Lac St-Jean, province de Québec. R. R. McKibbin, H. J. Atkinson, et C. S. Boons, Division de la Chimie, Collège McDonald, P.Q.

Les profils des tourbes de cinq tourbières dans deux régions générales de l'Est du Québec ont été étudiés et il a été fait une analyse des échantillons représentatifs prélevés sur les différentes couches. En général, la surface de ces cinq tourbières est du type de "haute tourbière" mais les couches organiques inférieures sont beaucoup plus riches en azote et en calcium, et la couleur noire et l'état friable de ces couches révèlent également un état de bonne décomposition. Parmi les éléments fertilisants généralement employés la potasse et le phosphore sont ceux qui font le plus défaut dans ces couches inférieures. Le brûlage de surface de la tourbe mousseuse de ces régions est nécessaire, mais c'est commettre une grave erreur que de pratiquer un brûlage "complet". Les conditions climatériques normales de ces régions empêchent de faire un tel brûlage complet en une fois et rendent difficile l'enlèvement nécessaire de la tourbe mousseuse dont on doit se débarrasser.

THE FATE OF PHOSPHATE IN THE SOIL[1]

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During recent years much study has been devoted to the subject of phosphorus in soils and to the fate which awaits the element when added in the form of fertilizer.

Of the three elements—nitrogen, phosphorus and potassium—considered generally as the primary constituents of fertilizers, phosphorus is the one which encounters the greatest danger of becoming lost, through the combining or fixing influence of certain strong soil bases, notably, Al, Fe, Ca and Mg. In some alkaline soils the fixing power is so great that only a small proportion of the PO_4 added may remain available for assimilation by the plant. The reaction between PO_4 and colloidal clay is usually very rapid, and in alkaline soils Ca and Mg may fix PO_4 in insoluble forms.

As a result of his studies of the subject, W. H. Lohse, at Guelph, concluded that PO_4 added in the form of the dicalcic $CaHPO_4$ might be less susceptible to fixation than the mono-calcic $CaH_4(PO_4)_2$, whereas Hibbard of California found the reverse, in a certain experiment, but in another that the easily soluble ammonium phosphate was fixed most readily, tending to confirm Lohse's opinion. Reactions are influenced, of course by the character of the soil, its moisture content and pH index. So many factors have to be considered that one may become bewildered in the quest for a solution. The pH of the soil is certainly an important factor, and the availability of the PO_4 is influenced to a great extent by the concentration of Ca. In other words, the removal of Ca increases the solubility of the PO_4. The solubility of PO_4 is greatest in its combination with water, next with NH_3, Na, K, Mg and Ca, in that order. Even in the presence of Ca and Mg, the addition of NH_3 to the soil seems to increase the solubility of PO_4.

There is no doubt that in certain acid soils where Al toxicity may be a menace, a considerable amount of PO_4 is used up in precipitating the soluble Al.

Years ago, at Rothamsted, it was found that soluble silicates, such as Na_2SiO_3, increased the yield of barley, on soils deficient in available PO_4; and other investigators have found evidence that soluble silicates increase the solubility of PO_4. Indeed, Na in combinations other than with silica undoubtedly exerts a favourable influence on the solubility of PO_4 in the soil, forming presumably Na_3PO_4.

The placement of fertilizers in the soil, or methods employed in their application, is a matter receiving much attention now, and this is again largely a phosphate problem, for it is well known that, owing to fixation, the PO_4 of superphosphate may be practically all retained in the upper inch layer of the heavier soils, when the fertilizer has been applied on the surface. This is an argument in favour of the drilling in of fertilizers, or their placement in the zone of the plant root system and in an accessible position. Results of trials indicate that, as compared with fertilizers broadcast,

[1] Paper read before a joint session of the Western Canadian Society of Agronomy and the Soils Group of the C.S.T.A. at the University of Alberta, Edmonton, June 27, 1935.
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half the amount drilled in will suffice to produce the same increase in yield of the immediate crop. This applies also to cultivated crops, such as potatoes, corn, roots and vegetables, for which the fertilizer may be placed in bands or strips on one or both sides of the row. Another factor is introduced here:—namely, a means to avoid fixation, of the phosphate primarily. That the finer the soil particles, the greater their fixing power is a recognized fact. Similarly, the finer the phosphate particles, the greater their exposure to the fixing action. When, therefore, the fertilizer is applied in rows or bands, it is natural to suppose—indeed experience indicates it—that an interaction among the fertilizer constituents themselves occurs, resulting in the formation of compounds easily attacked and absorbed by the plant, as compared with more or less insoluble compounds which may be formed through the union of PO_4 with strong soil bases, when the fertilizer is broadcast.

The same principle may be said to operate when fertilizers are added in granular or pellet form, the granule of superphosphate offering less exposure of its substance to the fixing action of soil bases.

This seems to have been established by Lohse who found that, within certain limits, the larger the granule of superphosphate, the greater the recovery of PO_4 from the soil to which it was applied. Similar results were obtained by A. R. Midgley of Wisconsin. In 1931 S. D. Conner of Indiana reported the results of an experiment on corn, in which he compared a granular fertilizer with the same fertilizer finely ground, and obtained returns very distinctly in favour of the granular fertilizer.

Some years ago Midgley made trials with superphosphate placements in a bluegrass sod. He cut knife grooves in the sod, 4 inches apart and 6 inches deep, depositing the superphosphate in the grooves. Compared with a surface application, the subterranean placement gave an increased yield of over 70%. Later, he found that a 3-inch depth was better than 6-inch.

My own experience coincides with the foregoing. In 1931 I obtained from our associates in England a large quantity of a double-strength fertilizer prepared specially, and in granular form. The formula for potatoes was 8–16–20, and this was compared with the ordinary 4–8–10, the latter being applied at twice the rate of the former. The trials were conducted at a number of points in the Maritime provinces, Quebec and Ontario, several of them on Experimental Stations. In approximately 75% of the trials the results proved favourable to the double-strength 8–16–20.

In the following year I decided to repeat the experiment, and the results this time were reversed, the 4–8–10 beating the 8–16–20 in a large majority of the trials. Now, the main reason for this, in my opinion, is that, whereas in the initial trials the 8–16–20 was in granular form, in the second year we made up our own 8–16–20 from non-granular monoammonium phosphate (12–56), ammonnium sulphate and muriate of potash. I am aware of the danger of giving reasons for one's conclusions. The conclusions may be right and the reasons all wrong.

When the company which I represent decided to engage in the manufacture of superphosphate in Eastern Canada, we adopted what is known as the Oberphos process, for the reason that it produces a granular, dry superphosphate containing 20% of available P_2O_5 when high grade rock is

employed. This means that, in order to prepare the hitherto standard 16% superphospahte, a filler, or diluent, must be added to the 20%. There is now, however, a general trend in favour of the 20% grade.

The Oberphos process differs widely from the old den method. The latter need not be described further than by the remark that the mixture of rock and acid are stirred together mechanically and then dumped into the den below, where the mass solidifies, and is finally excavated and placed in piles to cure.

In the Oberphos process there are two charging tanks, one containing the measured quantity of sulphuric acid, the other that of powdered phosphate rock. These, in total amount of about $7\frac{1}{2}$ tons, are drawn through a mixing valve into a large autoclave cylinder where the mixture is rotated under heat and vacuum, for about an hour. The confluent streams of acid and powdered rock pass through the mixing valve in the space of about 50 seconds.

At the conclusion of the "cooking" period, the man-hole of the autoclave is opened and the superphosphate emerges in dry, granular form. The bulging of the autoclave sides to the centre facilitates the discharge of the material. Through screens of different mesh the superphosphate is prepared in varying grades of fineness to suit the taste of customers, though more and more preference is being shown for the larger granule.

THE SOIL DRIFTING PROBLEM IN THE PRAIRIE PROVINCES[1]

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Wind erosion of soil has received so much attention recently that one almost hesitates to say any more about it but the problem is so acute and the suffering from drifting soil so widespread that it is quite necessary to continue to discuss the subject. It is not my intention to enter into a dissertation of detailed methods of drift control. I have recorded my opinions of this in collaboration with Dr. Hopkins, Mr. Barnes and Mr. Chepil, in the bulletin, "Control of Soil Drifting in the Prairie Provinces," just issued by the Dominion Department of Agriculture. Undoubtedly you will be free in your criticism of this bulletin. We hope you will for we are all anxious to arrive as nearly at the truth of the matter as possible.

While I do not intend to deal with control methods in detail, I do desire to present my own conception of certain phases of the soil drifting problem, as it is essential that we crystallize our ideas so that we can give the proper guidance to farmers right now.

First, as to the seriousness of the situation, soil drifting is undoubtedly one of the greatest difficulties that the grain farmer of the prairie has to meet. In some localities and on certain soils soil erosion has reached the proportions of a calamity during the recent drought years. It is well to remember, however, that while there is more or less drifting on all parts of the Prairies it is confined mainly to summer-fallowed lands. A total of 12,993,000 acres of land was summer-fallowed in the three Prairie Provinces in 1932 so the acreage of potentially driftable land in that year was about thirteen million acres. Of course there has been some drifting on fields that were not fallowed, but the total acreage has not been important.

It is necessary to understand also that while any fallowed piece of land may drift not all fallows have drifted. Every student of the subject realizes that certain soils do not move as readily as others. Medium textured loam soils that are not extremely high in organic matter do not drift readily unless improperly handled, but sandy soils and clay are difficult to hold. Soil Surveys made in Alberta and Saskatchewan indicate that over half of our soils are of the medium textured loams, about 15% light soils, and 25% are clay and clay loams. Fortunately most of our soils are of the intermediate types that are most easily kept from drifting. In fact, methods have been practised for years on these loams that have effectively controlled drifting even on fallows that have been kept clean of growing vegetation. The success of these methods in localities where winds are more severe than on most parts of the prairies inspires confidence that summer-fallowing for grain production can be continued without extreme difficulty on loam soils. The problem of drift control on this kind of soil now seems to have reached the point of applying tested methods. Fortunately these methods are not difficult, consequently it should be possible to have them quite generally adopted wherever needed.

[1] Paper to read before the Soils Group of the C.S.T.A. at the University of Alberta, Edmonton, June 25 1935.

[2] Assistant Superintendent.

It is not intended to infer that drifting can be absolutely prevented on any soil type or that no better methods are needed. It is encouraging however, to feel that on a portion of our soils wind erosion may be largely prevented.

The sandy soils present an entirely different situation. Only in the most favoured localities are they being farmed with success, while on all the drier parts of the prairie there seems to be little question that many of these light soils should not be used for grain growing, especially under our present conditions of low prices.

Where the rainfall is sufficient to produce good crops on sandy soils, control methods are developing, and some farmers seem to be meeting the situation successfully. Practices are not as well standardized as on the loam soils, however, and serious drifting is still in evidence. Considerably more information is needed regarding the handling of light soils.

About the same condition of drifting prevails on the clay soils as on the sandy areas but as these are some of our most productive soils their control is of great importance. Here again a number of farmers seem to have the condition well in hand even where the wind is severe which indicates the possibilities of control on the heavy soils. Serious drifting has occurred in many clay soil areas this year, however, which shows that much work must yet be done before the problem can be considered to be approaching solution.

As soil type influences the seriousness of wind erosion and the difficulties encountered in its prevention, so also do wind velocities and frequency, snow covering, type of weed and other plant growth, and other factors some of which are not yet known. As an example, the handling of stubble infested with a dense growth of Russian thistle is an entirely different proposition from handling clean stubble where it is desired to preserve a trash cover on a ploughless fallow.

Regardless of the variety of conditions met with in different localities, however, there are some definite principles that have general application. Bare fallows, for instance, may be used on medium loam soils under proper conditions, but sandy or clay soils require the mechanical protection of foreign material. This means that while ploughed fallows may be used on loams, they are not safe at all on sand or clay unless cover crops are planted as protection. These more difficult soil types therefore should be protected either with a crop or trash cover or both.

Another condition that appears to have general application is that with a wide unbroken sweep the wind carries more drifting material than it does over narrow strips and therefore its sand blast action is greater on unstripped land. This seems to be at least one reason why strip farming assists in control in most if not all localities.

In solving the soil drifting problem, then, one of the first requisites is to determine the soil types and to remove some areas from cultivation as soon as possible; the widespread application of the best practices so far developed should be stimulated by a proper extension programme; the attention of investigators should be centered principally on developing control methods for the more difficult soils, especially clay.

THE ROLE OF TREES IN MODIFYING THE AGRICULTURE OF THE DRY AREAS OF THE PRAIRIE PROVINCES[1]

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The drought which has been more or less general over large areas of our Prairie Provinces during the past five years has created probably the most serious problem which has faced our agricultural population since the country was first settled. It has had a disastrous effect on business generally, has entailed an enormous expenditure of public funds for relief, and has taken on the dimensions of a national calamity. Governments through their technical officials have been studying the problem intensively in an effort to arrive at some solution which will not only correct conditions as soon as possible, but it is hoped, and this is the most important feature, will tend to make impossible the amount of loss and suffering which might result during similar periods of drought which are bound to occur, judging from past history, periodically in the future. This would seem to indicate some radical change in the general system of handling our farm lands in the production of cereal crops in the affected areas.

There has been no lack of suggestions along this line, the press having been full of them during the past three or four years. Many of these suggestions have been advanced by responsible men who are conversant with the conditions and who have a knowledge of the practical difficulties involved. Many more, however, are sponsored by well meaning individuals who unfortunately are not sufficiently well informed as to conditions and lack practical knowledge of the farmers' problems.

One of the most popular ideas seems to be that drought can be controlled, the climate changed and rainfall increased, by the wholesale planting of trees. Has this widespread popular opinion any basis in fact? As a matter of fact there is no scientific basis for, or data to support, the assumption that either climate can be changed or precipitation increased as a result of any tree planting programme which it might be practical to undertake on farm land specially adapted to cereal cropping. The fact that it is these two supposed benefits which are the ones most stressed by the average advocate of tree planting is most unfortunate, as a great deal of adverse criticism has been aroused, the critics entirely losing sight of the fact that there are many other benefits of considerable economic value to be derived as a result of well developed tree plantations.

The possible improvement in agricultural conditions that might be brought about by a wider planting of trees may be considered under two main divisions. First, home shelter belt planting, including protection for gardens, stable yards and small adjoining pastures; and second, field crop shelterbelts for the protection of cereal and forage crops.

HOME SHELTER PLANTING

It is generally admitted by those who have studied the situation in an endeavor to arrive at some agricultural policy which will guard against a recurrence of the present conditions that what is needed is to make each individual farm self sustaining during periods of drought and depression. This is where the farm home shelter plantings can play a very important

[1] Paper read before a joint session of the Western Canadian Society of Agronomy and the Soils Group and Engineering Group of the C.S.T.A. at the University of Alberta, Edmonton, June 26, 1935.
[2] Chief of the Tree Planting Division.

rôle. Everyone familiar with prairie conditions knows that in average seasons, and particularly during periods of drought, it is practically impossible to grow a good supply of vegetables without adequate shelter.

The economic value of the farm garden perhaps has never been fully appreciated, but this has been shown up very definitely during the past four or five years. In many cases the produce from a good farm garden has kept the farmer and his family off relief. Several letters to this effect have been received in our office during the past two years. With suitable shelter a supply of home grown vegetables and hardy fruits can be practically assured unless conditions are extremely abnormal. These home shelter belts might well be extended to enclose small pastures and winter feeding paddocks on the average farm.

There is no object in further taking up time in discussing the value of the home shelterbelt. The advantages and benefits derived from such plantings have been amply demonstrated in all sections of the Prairie Provinces during the past thirty years. In passing one might mention the aesthetic value of such shelterbelts, which probably is equal to, if not greater than, the economic value.

FIELD CROP SHELTER BELTS

The idea of field crop shelters is only going a step further, and there is no reason to suppose that suitably disposed belts would not have a very beneficial influence. In just what manner do shelterbelts benefit growing plants? They protect them from mechanical injury during severe windstorms. By lessening the force of winds they decrease evaporation of moisture due to transpiration. They help to accumulate and hold snow during winter time. They also have a tendency to check soil drifting. We are quite ready to admit that there is no great amount of scientific data on this subject. We know of no actual research or experimental work that has been done in Canada to determine the influence of shelterbelts on field crops. From general observation, however, in many districts very marked benefits have been noted, both in the saving of crops from drifting and in increased yields. One of the first authentic observations is mentioned in a very early report by the late Dr. Saunders, then Director of Experimental Farms. Referring to a visit made in the spring to the Experimental Farm at Indian Head after a very severe windstorm he stated that he found the protective influence of a shelterbelt ten feet high had extended out five hundred feet. He says:—"We had a field of barley sown along side of one of the belts and other fields of grain at other points. The protective influence of the belt was very marked. The storm had been a very violent one, and the trees were about fifteen feet high and for seven hundred and fifty feet out the grain was green and well protected and in good conditions, while beyond that it began to get thinner and thinner, and for a few feet it was entirely obliterated. There the whole crop was wiped out, the wind blowing the plants out of the ground. We measured this at several points and found that for each foot of growth there was about fifty feet of protection."

On the Nursery Station at Sutherland some years ago there was a very striking demonstration of the effect of very low hedges, then only two or three feet high, in checking injury from early spring winds. In that case twenty acres of summerfallow protected at fairly close intervals by

these tiny hedges produced a crop of oats 45 bushels to the acre. An adjoining unprotected field of twenty acres, prepared in exactly the same way, was completely blown out. On neighboring farms the crop that season was practically a failure. Other equally striking examples at different places have been observed, which clearly show in a small way the value of field shelters in protecting crops from spring drifting. One season we made measurements and observations on a large block of summerfallow where the owner had planted out caragana hedges, then about seven feet high, and we found a very considerable increase in the height and density of the grain and the size of the heads for over two hundred feet back from the hedges. In 1931 on this same farm $16\frac{1}{2}$ bushels per acre of No. 1 wheat was produced on one hundred acres of summerfallow, while the best yields in the Indian Head district that season were not more than 6 to 8 bushels and many crops a complete failure. There was in this instance nothing to account for the increase in yield on this farm except the presence of the hedges, which must have checked a certain amount of surface drifting and helped to decrease evaporation during the season.

We have on file in our office quite a number of letters from farmers who during the past ten years have planted field shelters in a small way. Many of these claim that decided benefits have been apparent in checking drifting and increasing yields both of forage and grain crops. Such plantings have not been done in any systematic manner and no records of actual cost of planting and maintenance made to balance up against the extra yields. Considerable research work is necessary along these lines to determine the actual economic value of such plantings. Such data must be procured over a period of at least ten to fifteen years to be of any real value.

In certain sections of Russia topographical and climatic conditions are very similar to those in this country. Considerable planting has been done in these regions, and there are at least some authentic data available as to results. We have a translation of a bulletin by Professor N. I. Soos, published by the State Scientific Institute of Melioration at Leningrad in 1926. The results of apparently careful research set forth in this bulletin bear out the observations made under similar conditions in our own Prairie Provinces.

Record of snow gathering experiments using different methods such as building of snow mounds, staking brush and shelter belts show very greatly increased yields on adjoining crops for the years 1918, 1920, 1921, 1922 and 1923. The year 1919 was wet, and no advantage was apparent that season. In 1918, where snow had been accumulated, fall rye showed an increased yield of 57.7 poods (1 pood = 40 lbs.) per dessiative (approximately 2.7 acres), in 1922 an increase of 50 poods and in 1923 an increase of 62 poods. Similar results were shown with wheat, sunflowers and potatoes.

Planted tree shelters were found to be the most practical and economical method of holding the snow. The following is a quotation from this bulletin, and is supported by several tables giving accurate yields in protected and unprotected fields:—

"The influence of shelterbelts upon absolute relative humidities may be disregarded, but the good influence of these upon farm crops, due to

snow accumulation, and reducing wind velocities is sufficient to commend them. Observations made on the influences of shelterbelts at various times fully confirm the theoretical assumptions. Out of a number of observations showing benefits due to shelterbelts we take the liberty of quoting only those made at Krasno-Kutsk and Kameno-Steppe experiment stations which are more complete, being carried out by experienced organizations."

There is not time in a short paper to consider in detail the results given in this bulletin, but they show very decidedly the benefits to farm crops derived from shelter belts.

So far as we are concerned in Canada it remains to be proved whether field shelters are economically practical under our system of agriculture, and it is to be hoped that this question will be definitely settled in the future after actual demonstration on sufficiently large areas. We expect that a few such areas will be developed in the near future under the Prairie Farm Rehabilitation Act. In fact, a start has been already made by planting some 88,000 seedlings on a group of farms near Conquest. This planting will be considerably developed in the next few years.

CONCLUSIONS

From information at present available we are not prepared to advocate any general or widespread planting of field crop shelterbelts, but we believe benefits from such shelters can be reasonably expected and therefore feel that individual farmers who may wish to establish belts of this kind should be encouraged and assisted in so far as the resources of the Dominion Forest Nursery Stations may permit.

In the past one of the main objections has been that these hedges cut the land up into small fields which could not be economically worked with modern farm machinery, but in areas where strip farming is adopted, and this method is being more or less generally advocated in many districts, no serious difficulty has been experienced in working much narrower strips than would be necessary if the fields were subdivided by tree belts.

It is true that it would be perhaps four or five years before any benefits were apparent and that considerable labour during these earlier years would be necessary in cultivating and developing the belts. In some cases there will be trouble with such weeds as Russian Thistle piling up. In areas subject to drifting it will be necessary to follow such tillage methods as may be found advisable to hold the soil to prevent soil banking up the belts.

In connection with any scheme of tree planting, especially in the drier areas, it must be borne in mind that every advantage must be taken during cycles of normal moisture to get the plantations established. It is quite impractical to start shelterbelts in these dry districts during protracted periods of drought.

We do not make any extravagant claims as to what shelterbelts will accomplish nor do we consider that the planting of trees alone will provide a solution to the soil drifting and drought problem, but we do believe that planting carried out practically and intelligently, in combination with approved cultural methods, is just one agency which may help to ameliorate conditions such as we have recently been experiencing.

IRRIGATION IN ALBERTA[1]

E. E. Eisenhauer[2]
Lethbridge Northern Irrigation District

PROJECTS IN OPERATION

Irrigation farming is one of the oldest methods of farming in the world, and plays a very important part in the agricultural life of Alberta. In areas where the rainfall is not sufficient to produce a crop it is necessary to have artificial application of water in order to farm successfully. This has necessitated the development of large blocks of irrigated land in the southern and southeastern parts of the province.

Irrigation was first developed in Alberta by the ranchers who used the water from the creeks in the foothills to flood the low lying lands near these creeks to provide hay for the use of their stock in the winter. From this early development has grown the large irrigation schemes we have at the present time. This development has followed along several different lines. Some schemes were developed by large corporations, notably the Canada Land and Irrigation Company with their tract centering on Vauxhall, west of Medicine Hat; the Alberta Railway and Irrigation Company scheme, now known as the Lethbridge section of the Canadian Pacific Railway Company, centering at Lethbridge; and the Canadian Pacific Railway Company Irrigation Project east of Calgary. These were schemes owned and operated by companies who controlled both the land and the water. The land was sold with a water right to the incoming settler, who had to pay, in addition, an annual water service charge to cover the cost of maintenance and operation.

From these schemes there developed other irrigated tracts. We have the Taber, Magrath and Raymond irrigation projects where the farmers owned the land, bonded it and purchased their water supply from an irrigation company—in each case the Canadian Pacific Railway. Under this system the farmers, realizing that they could not produce sufficient crops under dry farming methods, agreed to bond their land to pay for the cost of installing the irrigation works and then paid the Canadian Pacific Railway Company for the water. In addition they have to pay a yearly annual charge to cover the cost of delivery of the water as well as enough to cover the payment of the bonded debt. This varies from $2.00 per acre to $5.00 per acre per year.

The next development was projects which were farmer owned and farmer operated, such as the Lethbridge Northern, the United Irrigation District, and some other smaller ones. In these cases the farmers banded together and under provincial legislation promoted irrigation schemes that had been previously surveyed by the Dominion Irrigation Engineers under the Dominion Department of the Interior. Here the farmers owned their land, bonded it for installation of irrigation works, then set up their own operation boards and assessed the land to pay for the costs of the bonds as well as yearly operating charges. Most of these schemes come under the supervision of the Provincial Irrigation Council, and many of them, in order to sell their bonds, had the backing of a provincial government guarantee.

[1] Paper read before a joint session of the Western Canadian Society of Agronomy and the Soils Group of the C.S.T.A. at the University of Alberta, Edmonton, June 27, 1935.
[2] Colonization Manager.

The most recent development in Alberta has been the turning over of the Canadian Pacific Railway Eastern Section, centering at Brooks, to the farmers, who in future will be responsible for the raising of funds to cover yearly operation charges and the creating of reserves to take care of any replacements as they may be required. The original idea in the opening up of the Eastern Section by the Company was to provide a sale for their land, and freight for their railways. It was always the idea that some day the farmers would take over the project and operate it themselves. That time has now arrived and in the final settlement the farmers obtained irrigation works to the value of $12,000,000 and land and sale contracts which brings the total value to $18,000,000. The farmers received this at no cost, and in addition were given $300,000 to cover two years operation charges. They are thus in a position, by careful management and with an active collection and land sales agency, to be able to operate successfully.

In the Province of Alberta we have at present some 942,363 acres of irrigable land which includes 12 large irrigation schemes, and 348 small private projects, representing a total original investment of over $35,000,000. In nine of these schemes, representing about 450,000 irrigable acres, the provincial government is either directly or indirectly involved. In the case of one, the Lethbridge Northern, the provincial government, under its guarantee of the bonded debt, has appointed an official trustee, and has, to date, written down the capital charge by over $2,000,000. As a result we are all very much concerned about irrigation. We are, in short, over expanded in irrigation. This over expansion was brought about due to a series of very dry seasons with low yields and correspondingly high prices. In addition the severe dust storms in Southern Alberta hastened this expansion. As a result the taxpayer is very much in the irrigation business. It is necessary for us to find the best way to handle these projects so as to salvage at least a portion of the original investment, as well as to encourage the irrigation farmer as rapidly as possible in the production of those crops which can best be grown under irrigation, and for which there is a market.

It must be apparent by this time to everyone that during the past few years irrigation has come into ill repute to those in the province who have had to help pay for it, both those who live on irrigated land and those taxpayers who are in other parts of the province, but who also have to help pay for these projects. It should however, be pointed out at this time that the benefits derived from irrigation are not wholly reaped by the irrigation farmer alone. Due to the development of irrigation we have many prosperous towns and cities; we have increased railway tonnage, specialized products for export, more thickly settled areas with larger tax paying ability, and other indirect benefits, so that the payment for irrigation schemes should not be wholly borne by the settler on irrigated land.

LAND SETTLEMENT

Irrigation development in every land where irrigation is practiced has been perfected from an engineering point of view and often in the classification of irrigated land the idea has been to use engineering standards. An outstanding irrigation engineer, Mr. W. Anderson, stated "that irrigation problems are really 10% engineering and 90% human." Because

we have had the proper soil conditions, plenty of sunshine, and lack of sufficient moisture to produce crops under dry farming methods we have in the past not always considered other features of suitability of land for irrigation development. The result has been that in recent years many of the irrigation projects have had to be reclassified, taking into consideration the productive ability of the soil, the location of the individual farm from market, and the topography of the land from the point of view of ease of irrigating. On this basis each parcel of irrigated land has a separate rating, and is now sold at a value corresponding to this rating. Thus a farmer knows in advance, when he purchases a piece of land, just what possibility he has of paying for it. He knows the productive ability of the land and the kind of crops most suitable and those which can be grown in the particular district. In this respect certain districts are more favoured with specialized crops than others. Irrigation farming is intensive farming, and the more specialized crops that can be grown and marketed the better chance the farmer has of success.

In order to successfully operate an irrigation project and to meet expenses, it is necessary to have the land settled as rapidly as possible. With so many different projects, each striving to get settlers, there has been some laxness in the selection of settlers for irrigated land. Because of the wide difference in the type of farming that should be followed under irrigation it is very essential that special care be given in the selection of settlers. Many farmers who would be successful under dry farming, turn out to be failures under irrigation. Then too, it is not always possible to get people who have had previous experience under irrigation. This, then, necessitates the setting up of some method of supervision and an advisory staff to enable the new settler to become acquainted as rapidly as possible with the best methods of irrigation farming. Irrigation farming, because of the intensive and specialized requirements, makes it necessary for the settler to have considerable capital, and more than the average managerial ability. In all irrigation areas in the world, considerable time and effort have been expended in trying to satisfactorily solve these two problems. This has given rise to a variety of schemes to provide the incoming settler with the financial assistance necessary to insure his success, and to the development of specialized crops to meet the higher cost of irrigated land. Each country has tried to solve these problems, but during the past few years the completely demoralized markets have been very trying for the irrigation farmer. The result has been in Alberta that the colonization of irrigated land is proceeding very cautiously, with special attention to the selection of the settler, placing particular emphasis on his ability and his desire to work and build up a home.

SPECIAL CROPS

In the past, and even today, many irrigation farmers are producing only those crops which come in direct competition with those produced by dry land farmers. This is undoubtedly a very great mistake, and must be rectified before the irrigation areas can become permanently successful. Irrigation lends itself in Alberta to the production of specialized crops. However, it must be borne in mind that crops produced must be disposed of, and it is very easy to over-produce certain specialized crops. In the

Lethbridge area we are fortunate in being able to raise sugar beets, and undoubtedly the sugar beet industry is outstanding in its benefits to irrigation farming. Not only does it give the farmer an opportunity to raise a paying crop, but at the same time he puts his land in excellent shape to raise other crops. It further affords him an opportunity to raise a crop that will help to control weeds, and it has been estimated by many that at least 25% of the land should be in sugar beets or a cultivated crop of some kind. It is impossible to over emphasize the importance of beet sugar production. At present we have one sugar factory in Southern Alberta, located at Raymond. This factory contracts for 14,000 acres of sugar beets from 800 growers. This requires 1,200 beet laborers who contract to thin, hoe and harvest the beets. The sugar factory has a maximum staff of 330 during the manufacturing period, which covers about three to three and a half months. The importance of this industry from a labour and financial point of view is illustrated by the amount of money put into circulation:—

Coal	$55,000.00
Lime	20,000.00
Bags	100,000.00
Coke	9,000.00
Boxes, etc.	125,000.00
Freight	330,000.00
Factory	175,000.00
Farmers	940,000.00
	$1,754,000.00

A large proportion of this is spent in the district immediately surrounding the factory. The Department of Agriculture of the United States estimates that a factory the size of the one at Raymond provides directly and indirectly sustenance for 10,000 people. You can realize then our great enthusiasm in having the sugar company agree to build another factory near Lethbridge, to handle an additional 7,500 acres of sugar beets in 1936. This factory is already under construction.

Alfalfa is the basis of all irrigated agriculture. The production of this cheap fodder encourages the feeding of livestock, at the same time increasing the fertility of the soil. With the use of legumes, such as alfalfa and sweet clover, cultivated crops such as sugar beets, corn and potatoes, beans and peas, the growing of grain such as oats and barley to be fed on the farm, and the production of wheat in small areas with large yields, the irrigation farmer is more likely to solve his problem than by the continued raising of wheat only. Through the raising of special seed crops such as different grasses, registered wheat, oats and barley, and in some places alfalfa and sweet clover seed, higher per acre returns can be obtained. Even with last year's prices we had net returns of $140 per acre in the raising of certain grass seeds.

The canning industry has only started to develop in our irrigated areas. Peas, beans, corn, pumpkins and tomatoes produce abundantly, and the factory at Taber aids in disposing of these specialized crops. The production of broom corn is reaching a very satisfactory stage, and the acreage is rapidly increasing.

The returns per acre under irrigation vary greatly, due to soil fertility, rotation of crops and the ability of the farmer. Naturally, of course, the price per unit is a large determining factor in per acre returns. The following figures give the returns from five farmers raising sugar beets and five farmers not raising sugar beets. In each case the farmers were slightly better than the average.

The sugar beet farmers had an average holding of 149 acres. They had average assets of $11,766 and liabilities of $7,494. They seeded an average of 27 acres of wheat, yielding 30 bushels per acre; oats, 16 acres, yielding 47 bushels per acre; alfalfa, 18 acres, yielding 2.4 tons per acre; and sugar beets, 37 acres, yielding 10.7 tons per acre. If all the crop they raised had been sold, the returns at market prices would have been $3,215 per farmer, of which $2,314 was the gross return from sugar beets.

The farmers not growing beets had an average land holding of 232 acres, showing assets of $21,109 and liabilities of $13,062. They seeded an average of 90 acres of wheat yielding 32 bushels per acre, 38 acres of oats, yielding 47 bushels per acre; 21 acres of barley yielding 45 bushels per acre; and 24 acres of alfalfa, yielding 3.2 tons per acre. If their total crop had been sold the returns would have been $2,601. In other words the beet grower had a gross return from his sugar beets alone almost equal to the gross revenue obtained for all the crops grown by the straight grain grower. I would like to point out that none of these average yields of grain are as high as they should be for successful irrigation farming.

The marked increase in favour of the sugar beet producer is due to a better rotation of crops, thus increasing soil fertility. Sugar beet production is certainly one of the avenues open to the irrigation farmer that will give reasonably steady returns.

TECHNICAL AGRICULTURISTS AID IRRIGATION PROJECTS

Now where is the place for the trained agriculturist in aiding the irrigation farmer? First of all very little definite advance has been made in the methods of irrigation applicable to Alberta conditions. The method of distributing the water is more or less haphazard. We have no simple method whereby the man in the field can have a reasonably accurate analysis of the soil he is farming and the water requirements of that particular soil. Each farm varies tremendously so far as the soil constituents are concerned, and the water requirements of the soil and crop being raised. This surely is a challenge to the specialist in soils and to the chemist. A start has been made by the soil classifications of the Soils Department of the University of Alberta.

Irrigation brings in its train new and varied plant diseases, and here is a field for very extensive work. As the type of farming followed by the irrigationist must be more varied than that of the dry land farmer, there must be more careful farm management, more accurate information regarding crop production costs, and an up-to-the-minute store of information as to the variety of crops to be raised. Here the economist has a large field that is almost untouched so far as Canada is concerned.

Until this work is done, and it is the technical agriculturist who must do it, the farmer does the best he can, and by the trial and error method is making slow progress. Irrigation in Alberta is a tremendous problem and a vital challenge to the training and ingenuity of the technical agriculturist.

THE EFFICIENT USE OF SOIL MOISTURE AS A FACTOR IN THE CONTROL OF DROUGHT[1]

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Experimental evidence suggests that the harmful effects of drought may be appreciably lessened by a more efficient utilization of available supplies of water. While drought indicates aridity, or the absence of water, the term, from an agricultural standpoint, is more frequently applied to a condition in which plants suffer and may be permanently injured because of insufficient amounts of water. In the open plains areas of Western Canada, where it is necessary to employ the so-called dry farming practices, a drought of this nature frequently arises. Moisture is of such importance in these areas that it is generally understood to be the limiting factor in crop production. In recent years this limiting factor has depressed wheat yields to as low as one tenth, or less, of the optimum and in some cases has been responsible for total crop failures.

For many years a number of experiments on soil moisture have been conducted under the direction of the Division of Field Husbandry of the Dominion Experimental Farms, Ottawa. These experiments have been made at the Swift Current, Saskatchewan station which is located in a typical dry farming and cereal producing area. Deep, watertight tanks, filled with soil as in the field, are used and crops are grown in this soil. The experiments are probably unique in that for the most part the only source of moisture for crops grown in the tanks comes from the natural precipitation. In most cases, too, the soil has remained in these tanks for a period of twelve years and has produced crops, either each year, or in alternate seasons, according to the requirements of the particular experiment. The crops do not appear to suffer in the least by their novel environment except through a shortage of moisture.

The use of tanks permits a very close observation of soil moisture utilization during crop growth through changes in weight of the whole mass. As the tanks are placed in the centre of small square plots, which are seeded to similar crops, it is assumed that the utilization of soil moisture by crops growing in the tanks is comparable with that of similar crops grown in the field. In these experiments it has been possible to segregate moisture present in the soil and available for crops from that received as precipitation during the growing period. This is readily accomplished by noting the difference in weight of the tanks between seeding and harvest. Rainfall received during this time is measured by the raingauge and the weight of water added from this source is calculated. Normally, of course, a greater or lesser amount of water from every shower is lost by evaporation. The extent of this loss is difficult to estimate, but as it also occurs in the field it is assumed to form part of the water utilized by crops during their growth.

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[1] Paper delivered before a joint session of the Western Canadian Society of Agronomy, the Soils Group of the C.S.T.A. and the Agricultural Engineering Group of the C.S.T.A. at the University of Alberta, Edmonton, June 24-26, 1935.

[2] Formerly Field Husbandman. Obit. August, 1935.

Much of the cultivated land in the dry farming areas of Western Canada is used for the production of cereal crops, wheat being the principal and, hitherto, the most profitable. The usual practice here, as in other countries with similar soils and climate, is to grow grain crops in succession; crop rotations which include a variety of crops have not been adopted to any extent. At intervals the land is summer-fallowed in order to secure control of weeds and to conserve moisture in the soil from a season's rainfall. A grain crop thus directly follows a previous crop of grain or is seeded on land previously summer-fallowed. Locally, these crops are termed "stubble" and "summer-fallow" crops, respectively and will be referred to as such in this paper. The important difference between these two crops is that the former are frequently subjected to very hazardous conditions because of an extreme deficiency in soil moisture. On this account stubble crops often return much lower yields of grain than summer-fallow crops.

One of the most striking features in the soil moisture experiments conducted at Swift Current is the comparatively high yields of grain grown in tanks as opposed to those secured from field and plot areas. This will be evident from the yields of wheat presented in Table 1.

TABLE 1.—YIELDS OF WHEAT ON SUMMER-FALLOW. SWIFT CURRENT, SASK., 1924–1925

Three-year Rotation (Summer-fallow : wheat : wheat)

Year	Yields in bushels per acre		
	Field areas 10 acres	Plot areas 1/50-acre	Tanks Dia. 15 inches
1924	34.6	—	46.9
1925	20.5	20.8	32.8
1926	22.0	20.5	44.9
1927	21.5	42.7	61.4
1928	36.8	33.5	59.9
1929	11.2	9.5	23.9
1930	16.3	19.0	25.5
1931	7.5	3.0	20.1
1932	15.3	9.3	25.9
1933	4.5	5.5	29.1
1934	6.3	7.3	20.2*
Average	17.9	17.1	35.5

*Crop injured by soil drifting.

The yields of grain from the tanks were of course quite small and were measured in grams. They have been expressed as bushels per acre in the above table for convenience. Although this practice appears to introduce a grave source of possible error, the conversion of grams of grain per tank to bushels per acre is accomplished quite readily by the use of a suitable factor, in this case 1.305. As all three crops were grown in the same general surroundings, in the same kind of soil, with the source of moisture the same and with the same kind of seed it seems remarkable that, over a period of eleven years, one should have yielded at a rate twice as great as the others.

With the exception of the 1927 season and two of the dry years 1931 and 1932, the yields of wheat from field and plot areas are not appreciably different. These yields, too, are indicative of the yields of wheat from contiguous territory. The outstanding feature of the tabulated data is the comparatively low yields in 1933 from field and plot areas, less than one-fifth of that secured from the tanks. This is all the more remarkable because such unusually low yields in that season were unexpected. The

chief causes for these low yields were assumed at that time to have resulted from injury by drought and grasshoppers. That this assumption is not entirely correct is evident from the fact that the crops grown in tanks were likewise exposed to these two hazards.

It will be of interest at this point to note the utilization of water by the crops grown in tanks over an eleven-year period, and this information is presented in Table 2.

TABLE 2.—UTILIZATION OF WATER BY WHEAT ON SUMMER-FALLOW, SWIFT CURRENT, SASK., 1924–1935

Year	Water from rain, inches	Water from soil, inches	Total inches	Total precipitation, inches
1924	7.73	6.10	13.83	33.37
1925	3.65	7.98	11.63	25.88
1926	6.00	8.24	14.24	25.28
1927	7.48	9.03	16.51	30.74
1928	7.63	9.77	17.40	32.88
1929	6.12	5.61	11.73	23.41
1930	4.83	4.55	9.38	20.50
1931	4.89	3.89	8.78	20.98
1932	7.89	3.77	11.66	25.49
1933	4.31	6.86	11.17	27.84
1934	5.89	5.42	11.31	24.41

The above data will probably prove a surprise to many readers, particularly those interested in the correlation of rainfall with wheat yields. In five out of eleven seasons the crop actually secured more water from the soil than it received as rain during the growing period. Actually the frequency has been much higher as a crop can only utilize that portion of the water from rainfall which penetrates the soil; an appreciable proportion is lost by evaporation. The water which aids in the growth of wheat seeded on summer-fallow, therefore, comes largely from precipitation received during the period prior to seeding time and extending back some twenty months, in fact, to the time when the previous crop was harvested. It is perhaps relevant to mention at this point that under dry farming conditions a normal crop of wheat seeded on summer-fallow effectively disposes of all available soil moisture within reach of its root system, in addition to whatever amount is available from the seasonal rainfall.

Another striking feature about the data presented in Table 2 is the relatively small proportion of the total precipitation which actually functions in the production of crops. In most cases there is a loss of more than 50% of the total precipitation, largely by evaporation, but also to some extent by run-off, and these losses are proportionally greater when the visible supply of moisture is less than normal.

Table 3 has been prepared from the data contained in Tables 1 and 2. This indicates the number of bushels of wheat produced from each inch of the total water supply.

TABLE 3.—YIELD OF WHEAT FROM EACH INCH OF WATER SUPPLY, SWIFT CURRENT, SASK., 1924–1934

Year	Field areas, bushels	Plot areas, bushels	Tank areas
1924	2.50	—	3.39
1925	1.76	1.79	2.82
1926	2.30	1.44	3.15
1927	1.30	2.59	3.72
1928	2.11	1.92	3.44
1929	0.95	0.81	2.04
1930	1.74	2.03	2.72
1931	0.85	0.34	2.29
1932	1.31	0.80	2.22
1933	0.40	0.49	2.60
1934	0.56	0.65	1.79

The data from the tank areas may be divided into two groups including the years 1924–1928 and the dry years of 1929–1934. In these groups the value of each inch of water in producing wheat is remarkably uniform. No such uniformity appears in the yields of grain from field and plot areas, although all received the same amount of precipitation. It appears reasonable to conclude, therefore, that yields of grain from the latter were affected by some factors which did not operate against the grain grown in tanks.

Normally grain crops are exposed to certain hazards during their growth. These consist chiefly of attacks from plant diseases and insect pests, competition from weeds and in many parts of Western Canada a deficiency in soil moisture. In this discussion it is not proposed to deal with the influence of plant diseases nor with insect pests as all the crops studied were equally exposed to these hazards and presumably were affected more or less to the same extent. An exception occurred in the case of injury to grain from the wheat stem sawfly. Stems of grain, severed by the larvae of this pest, could be salvaged for the crops grown in tanks, but were lost to some extent on the field and plot areas.

The chief hazard to crop growth appears to arise from competition for soil moisture by weeds. The seriousness of the competition from this source can be gauged from data presented in Table 4. These data were secured from experiments conducted with soil contained in tanks in which wheat and the weed Russian thistle were permitted to grow together. In each year the crops were seeded together in previously summer-fallowed land.

TABLE 4.—WHEAT YIELDS AS AFFECTED BY COMPETITION FROM RUSSIAN THISTLE, SWIFT CURRENT, SASK., 1931-1934

Year	Wheat grown with weeds					Wheat free of weeds		
	Water from rain, ins.	Water from soil, ins.	Total water used, ins.	Yield of wheat, bus.	Proportion of grain to total crop, per cent	Total water used, ins.	Yield bus.	Proportion of grain to total crop, per cent
1931	4.89	4.71	9.60	9.0	9.1	8.78	20.1	39.3
1932	7.89	4.12	12.01	17.2	19.1	11.66	25.9	34.4
1933	4.31	6.71	11.02	6.8	6.7	11.17	29.1	39.7
1934	5.97	4.98	10.95	14.2	20.8	11.31	20.2	32.7

The weed Russian thistle *(Salsola pestifer)* forms only one of several kinds used in these experiments. It has been selected for special mention here as this weed has spread enormously over the cultivated areas of Western Canada during recent years. This is not all together surprising for relatively hot dry weather favours the growth of such a weed, while frequent and variable winds effectively disseminate its numerous seeds. Russian thistle is particularly economical in the use of water, that is to say, it produces a relatively large amount of plant material for the quantity of water used. This economy in the use of water, however, is more than offset by the enormous size of individual plants, if allowed to grow unhindered, or the very large number of plants, so that these can easily become serious competitors for soil moisture with economic plants like wheat. The data presented in Table 4 indicate that when using almost identical amounts of water, the grain from Russian thistle infested land may be only a fraction of that from land free of weeds. In this connection attention is directed particularly to the 1933 figures. In June of that year unusually warm weather was experienced, with maximum temperatures in the shade increasing steadily from 93° F. on the thirteenth of the month to 102° F. on the sixteenth. This very hot spell appeared to temporarily check the growth of wheat plants, but gave a decided stimulus to the growth of Russian thistle.

Reference has already been made to the fact that crops seeded on summer-fallow may secure more water from the soil than is received as rainfall during the cropping season. If, during the summer-fallow period, the land is permitted to become weedy, there occurs an appreciable loss of water and this loss, although occurring a year before the land is seeded, is invariably reflected in the yields of subsequent grain crops. Such loss of soil moisture through weeds may occur at even an earlier period. A common practice in the grain producing areas of Western Canada is to grow two crops of wheat in successive seasons and to follow with a period of fallow, thus completing a three-year rotation. Frequently the second crop of grain becomes very weedy and this has been particularly true during the recent dry seasons when a deficiency of soil moisture hampered the growth of grain crops. When these crops have been harvested the land is frequently left untouched until the following season when it receives preparatory treatment for the summer-fallow period. Some weeds, particularly Russian thistle, grow quite vigorously after harvest up to the time of the first severe frost and effectively dissipate any soil moisture which might have been conserved at this time. That this moisture, although conserved in the soil some eighteen months before it is utilized by grain plants, is of great importance can be realized from the fact that of the moisture conserved during a complete period of summer-fallow, approximately twenty months, from 10 to 64 per cent has been conserved during the first three or four months.

CONCLUSION

The results of soil moisture experiments conducted at Swift Current have shown that moisture is not used efficiently in the production of grain crops. The evidence indicates that competition, direct and indirect, from the growth of weeds probably forms the most serious menace to crop production in areas where supplies of moisture are deficient.

Résumé

L'utilisation efficace de l'humidité du sol comme facteur dans le contrôle de la sécheresse. S. Barnes, station fédérale expérimentale, Swift Current, Saskatchewan.

Les résultats des essais sur l'humidité du sol qui ont été conduits à Swift Current ont fait voir que l'humidité disponible n'est pas utilisée de façon efficace dans la production des récoltes de grains. Les preuves recueillies indiquent que la concurrence directe et indirecte de la végétation des mauvaises herbes est peut-être le danger le plus sérieux à la production des récoltes dans les régions où la provision d'humidité est déficitaire.

THE USE OF TILLAGE MACHINERY IN SOIL-DRIFTING AREAS[1]

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Land must be worked with tillage machinery in order to control the weeds and prepare the soil for the crop. The soil must also be conditioned to resist the effect of the wind. The soil should be worked as little as possible. When working the land, the correct machine should be used for a definite purpose.

The drag harrow has frequently been used with disastrous results as a weed control machine, when the soil was too dry and in a condition that it became pulverized to a point where it blew badly. The drag harrow is a valuable weed tillage implement to be used primarily after seeding, whenever the moisture content of the soil is such that the soil remains in a lumpy condition after its use. In such cases the drag harrow is one of the most economical weed control implements.

The spring tooth harrow is becoming more and more common as a pre-seeding tillage implement in sandy and heavy clay soils. When equipped with the narrow shovels it penetrates the soil well, bringing up fresh moist soil which forms lumps. Its use also destroys fine small weeds before seeding and it pulls lighter than the cultivator. The 16-foot spring tooth harrow may be drawn in clay soils with a pull of 1000 lbs. The spring tooth harrow with the long pointed teeth is also valuable in pulling out undergrown roots such as couch grass.

The disc harrow is an implement very well suited for light tillage on stubble in the fall in order to cover weeds for early germination. Its use on heavy clay soils in the spring is quite safe and effective for eradicating a crop of weeds and bringing up moist clay lumps to resist wind action. The single disc harrow is preferable to the cultivator when the cultivator does not scour, and to the spring tooth harrow where more weeds are to be exposed. The disc harrow will cut and turn practically everything. The disc harrow is used effectively for the first tillage operation in preparing summer-fallow, to be followed by the one way disc, plow, or cultivator. It is designed for large horse units and for the tractor so that the tillage may be done at the most effective time as well as economically.

The disc harrow should never be used in sandy or loam soils which are dry or tend to pulverize easily. The finely pulverized soil will blow badly. Excessive use of the disc harrow will tend to ridge the soil sufficiently to become undesirable.

The one way disc is used in stubble instead of double discing, or spring plowing in preparing stubble land for crop. The one way disc cuts everything, may be worked at shallow or medium depths, and leaves the stubble in the soil to assist in resisting the action of the wind. The one way disc tends to pulverize the soil and leave it in a loose condition. It is a very effective weed control machine and where sufficient stubble is present leaves the soil so that soil drifting is well controlled.

[1] Paper read before a joint session of the Western Canadian Society of Agronomy, Soils and Agricultural Engineering Groups of the C.S.T.A. at the University of Alberta, Edmonton, June 26, 1935.
[2] Professor of Agricultural Engineering.

FIGURE 1. The one-way disc with seeder attachment seeding in sandy land.

It is a desirable implement for use in summer-fallow. Its use is not desirable for all of the summer-fallow operations. The soil becomes so loose and pulverized that, where the moisture content of the soil is low, the soil will blow in spite of the stubble or trash. The one way disc has been improved to such an extent that it may be used with reasonable success even in quite stony land. The presence of large field stone just under the surface of the soil has usually been the cause of serious breakage of the discs. The heavy duty heat-treated discs, however, resist the action of the stone almost unbelievably.

The one way disc seeder is a combination tillage and seeding implement which has rapidly been coming into use. The advantage of tilling and seeding in one operation, when the soil and weed growth are both in ideal condition for seeding and weed control, has long been recognized. Its use is effective and economical in tilling and seeding stubble land. Where the summer-fallow is firm and weedy the one way disc seeder may be economically used. There is usually the need for packing the soil after the use of the one way disc seeder. The ordinary packers are not very satisfactory unless they are loaded heavily. The surface packer tends to prevent the drying of the weeds exposed, thus hindering a part of the effective work of the one way disc. The packer is not effective if used a day or so after the one way disc seeder. Consequently, several using the one way disc seeder, particularly in clay soils, have built packers with plat discs for the subsurface packing elements. The discs run in two gangs offset so that a disc runs every 3 inches, thus packing the subsurface and not affecting the surface or the weeds to an appreciable degree. The one way disc is not as economical a machine to use for light fall tillage as the single disc harrow.

The single disc or double disc drills do not till the soil sufficiently to eradicate weeds or produce a lumpy surface on the soil, to be used without pre-seeding tillage. A weedy seed bed as well as a fine dusty condition which blows badly usually results where this practice is followed.

FIGURE 2. One-way disc in sandy land.

The hoe drill may be used in clay soil when the summer fallow is clean with oat previous tillage, particularly where the land may be cross harrowed without damage from soil drifting.

The stiff tooth cultivator is an implement particularly suited to the prairie soils as an implement for weed control. The use of the cultivator leaves the soil in a lumpy condition somewhat ridged which is ideal for resisting the action of the wind. The cultivator is not as effective in clay soils where the shovels do not scour. It is necessary in such soils to operate the cultivator much deeper than required for the best shallow tillage. The stiff tooth cultivator may be fitted with narrow shovels for spring tillage of summer-fallow before seeding; the narrow shovels penetrate better than the larger sweeps and leave the soil lumpy.

The cultivator is valuable to use as the tillage for the last operation in preparing summer-fallow before winter so that the soil will be rough and lumpy to collect snow and resist the wind during winter. The cultivator can be used after any of the other tillage implements quite successfully.

The furrow drill is a form of cultivator seeder which shows some merit as a combination tillage seeding machine. It is a machine fitted with lister shaped furrow openers spaced on 14-inch centres. The furrow openers are fitted with seed distributors at the bottom of the heel so that the seed is placed in two rows. A double packer follows in the furrow over each row of seed to pack the soil onto the seed. The machine is used on weedy summer-fallow after the fallow has been either disced or spring-toothed. It is used without pre-cultivation where the summer-fallow is clean. Pre-seeding tillage is necessary on stubble land before its use. The value of the machine is that the land is furrowed in order to prevent soil drifting. The soil is left in a lumpy condition even though sandy and light. The machine is fitted with cultivator shovels for summer-fallow tillage. The furrow drill is not in general use in Western Canada but may have some advantages which might well be studied.

The seeder plow is a combination tillage and seeding machine consisting of six small 7-inch moldboard plows mounted on a frame. The six plows cut 42 inches and turn the stubble or weeds; the seed is run ahead of the first bottom on to the bottom of the furrows. The following bottoms cover the seed with the furrow slice. The machines were not flexible for working in stony land and gave some trouble in scouring where heavy stubble was encountered; the stubble rolled ahead of the plows until the plows would plug. The seeder plow is used in the sandy loam soils primarily among those who were acquainted with the implement in their home land.

The rod weeder is a valuable machine used in the eradication of tap-rooted weeds such as Canada thistle, pigweed, and Russian thistle. The rod weeder should not be used as the last operation before winter. The rod weeder tends to pulverize the soil, leaving it too smooth and fine for best resistance to the wind. Its use also tends to separate the soil from the stubble which is not desirable. However, where followed with the cultivator the weeds are eradicated and the soil is left rough and well mixed with the stubble.

The plows, both moldboard and disc, are in general use as tillage machines. The moldboard plow is used in sandy loam and clay loam soils, where weed growth must be turned under for its control, also where it is necessary to turn under stubble or manure. The 14-inch moldboard plow is most efficient at from $4\frac{1}{2}$ to 5 inches deep. Deeper plowing is not only undesirable from a weed control standpoint, but also requires excessive power.

The disc plow is used where difficulty is experienced in scouring with the moldboard plow. The disc plow will go quite satisfactorily in shallow plowing ($4\frac{1}{2}$ inches deep), providing the discs are sharp. The stubble will be mixed in the plowed soil more desirably for soil drifting control than when using the moldboard plow. The setting of the scrapers on the disc plow can be made to cover the stubble and weed growth as in the case of the moldboard plow, or by raising the scrapers. The stubble can be left in the soil similarly to the work of the one way disc. The power required to pull the disc plow is not appreciably greater than that of the moldboard plow. The disc plow tends to pulverize the soil more than the moldboard plow. Where the plow is used for pre-seeding tillage a well loaded subsurface packer attached to the plow will tend to firm the seed bed so that seed germination will be uniform.

From the standpoint of power and cost per acre, the plow is an expensive implement to operate; the draft is higher per foot of weight than any other tillage implement. Thus, where it is possible to control the weeds with surface or shallow tillage implements without pulverizing or ridging the soil unduly, both spring and summer-fallow tillage may be accomplished more economically with surface tillage implements than when plowing.

ANNUAL MEETING OF THE SOILS GROUP OF THE C.S.T.A.

The annual meeting of the Soils Group of the C.S.T.A. was held at the University of Alberta, Edmonton, June 25 to 27, 1935.

The programme was prepared by the officers of the Group for 1933-34 who were: Dr. A. Leahey, University of Alberta, *Chairman*. Dr. R. R. McKibbin, Macdonald College, *1st Vice-Chairman*. Prof. Auguste Scott, Ecole Superieure d'Agriculture, Ste. Anne de la Pocatiere, *2nd Vice-Chairman*. Dr. J. Mitchell, University of Saskatchewan, *Secretary*. The papers presented have been assembled for this issue of Scientific Agriculture under the direction of Dr. Mitchell.

The following officers were elected for the year 1935-36.

Dr. R. R. McKibbin, Macdonald College, *Chairman*.

Prof. Auguste Scott, Ste. Anne de la Pocatiere, P.Q., *Vice-Chairman*.

Dr. J. S. Mitchell, University of Saskatchewan, *Vice-Chairman*.

Mr. E. M. Taylor, New Brunswick Department of Agriculture, *Secretary*.

BOOK REVIEW

The Rural Science Series, edited by L. H. Bailey. New York: The Macmillan Co., $7.00.

Weeds. W. C. Muenscher

To those who have been striving, in one way or another, to mark some little advance in coping with the redoubtable problem of weeds, the appearance above the horizon of light upon any phase of that task is reason for satisfaction. To have that light suffuse the whole weary vista of perplexity, with everything that is latest from all sources, together with what is best out of the confused counsels of the past, must surely spell joy. Such is the star to which Prof. Muenscher seems to have hitched his wagon, with no small measure of success, in the opinion of this reviewer.

For 500 weeds, in his estimation most entitled to consideration, he has very readably and yet concisely given the requisite treatment. This embraces names, popular and scientific; source, when not indigenous; distribution within our range, geographically and with reference to habitat and weediness; description, with due regard to morphology, reproduction, and field recognition; and finally control, so far as enlightened advice in itself can go in securing control of weeds. In no previous American publication have so many weeds been admitted to review; and in the present volume the selection has been restricted mainly to species of concern in the northern United States and Canada, few of which could reasonably have been ignored. For Canadians, naturally, some inclusions would have been omitted in favour of others left out, but the number is gratifyingly small, surprisingly small indeed, in view of the erratic distribution of so many introduced species, and no slight diversity of conditions even across a mere boundary line.

The weeds to be treated are arranged according to family, and then alphabetically by genus and species. Each consecutively bears a number by which it is known for purposes of cross reference. Similarly, reference to control measures, considered fully in a preceding portion of the book, is by identifying numbers. Reference to literature cited in a considerable listing of the more recent and important work, is by footnote. An index by all the various names and synonyms included is appended, and a quite original key to the groups and species, and running to 35 pages, facilitates identification of unfamiliar weeds. Most important species are also clearly figured fairly conveniently to the text. It is a student's manual in the very best tradition. In one respect perhaps it might have been improved; in lieu of the visual aid which a little space between weeds in the text would have provided (at the expense of compactness), the putting of each initial number in bold face type would have been some guidance to the eye. The placing in one figure of anywhere up to half a dozen species, with their parts, is another economy of space achieved out of a little extra demand on the student's patience.

Notwithstanding the exceptional number of weeds treated individually, 90 pages, or about one-sixth of the book, is still devoted to general discussion

of weeds and their control. This includes chapters on the nature, dissemination and importance of weeds, with numerous instructive tabulations not usually available in bulletins; lists of weeds of special habitats or crops; and their control by the various manual, mechanical and chemical means.

Recognizing by what diverse means weeds are scattered, prevention as a factor in control is duly emphasized. The fundamental distinction between eradication and control is also perceived, the former being applicable where weeds have gained a footing, but are not yet beyond bounds, while control measures are adopted when, without hope of complete eradication, weeds must be so subdued as to permit of continued cropping or other use of the area. The proper choice of methods demands a knowledge of the weed only to be gained by attention to its habits, present status, and occurrence in relation to crops. No less than 27 methods are discussed, and under one of these, the use of chemicals, upwards of a dozen of the most useful selective sprays are reviewed in the light of extensive recent investigations. It is not maintained that the use of chemicals is yet to supersede cultivation, particularly in large areas; although since recent work has shown "that on some soils the chief benefit derived by many crops by cultivation is the control of weeds," there is reason to watch developments. The rapid advance made by chlorate herbicides within the past decade, with the technique for their use still imperfectly evolved, is noteworthy to say the least. All methods have their place, those particularly which are part and parcel of accepted farm practice; and perhaps the real task confronting agronomists now is to contrive how to get more consistent and concerted action on the land—a vital matter on which our author has not touched.

Of weeds in Canada, establishing themselves unknown to most, we note among others: Austrian field cress, dog mustard, leafy spurge, hoary alyssum, Russian knapweed, clasping-leaved peppergrass, tarweed, whorled plantain and flixweed. These are the invaders which, by knowing in time, we might still hope to eradicate in some cases.

Altogether the author and publishers are to be complimented on an excellent piece of work. The book has been kept to a size convenient for use, is well bound and carefully printed, and clearly and faithfully illustrated. The nomenclature, in so many cases growing obsolete in existing manuals, is brought in line with current use. Common names may be expected to vary with locality, but in this instance, are quite largely acceptable to Canadians. It is hoped that investigators, teachers and extension men, as well as farmers and others, who can go beyond a low price for value received, will avail themselves of what is indeed a notable acquisition.

H. GROH